PENNSYLVANIA
GEOLOGICAL SURVEY
FOURTH SERIES

BULLETIN W 2

GROUND WATER

IN

SOUTHEASTERN PENNSYLVANIA

By

GEORGE M. HALL

of the U. S. Geological Survey

With Analyses by Margaret D. Foster and Charles S. Howard

(Prepared in cooperation between the United States Geological Survey and the Pennsylvania Topographic and Geologic Survey)

DEPARTMENT OF INTERNAL AFFAIRS
PHILIP H. DEWEY, *Secretary*

TOPOGRAPHIC AND GEOLOGIC SURVEY
GEORGE H. ASHLEY, *State Geologist*

HARRISBURG, PA.

1934

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PURCHASED FROM

BUREAU OF PUBLICATIONS

DEPARTMENT OF PROPERTY AND SUPPLIES

HARRISBURG, PA.

CONTENTS

ILLUSTRATIONS

ABSTRACT

Introduction. The area covered in this report on Ground Water in southeastern Pennsylvania includes that portion of the State lying south and east of Kittatinny, Blue or North Mountain, an area of approximately 8,000 square miles. All of Adams, Berks, Bucks, Chester, Cumberland, Delaware, Franklin, Lancaster, Lehigh, Montgomery, Northampton, Philadelphia, and York counties and parts of Dauphin and Lebanon counties lie within the area. Numerous published reports on the geology of the area were available and used by the author. The work of the Second Pennsylvania Geological Survey and later work by many authors are included on the Geological Map of the area compiled by Stose and Jonas. The hydrologic information was obtained from well drillers, engineers, and owners of wells and springs.

Climate. The climate is relatively mild and greater variations are caused by differences in altitude than by increase in latitude. The mean annual precipitation ranges from about 37 inches in Franklin County to approximately 50 inches in Philadelphia County. Precipitation is usually well distributed throughout the year but in phenomenally dry years like 1930 prolonged droughts may be experienced. Snowfall is heaviest in the South Mountain area. The mean annual temperature is about 52° F. Temperatures as high as 108° F. during the summer and as low as —40° in winter have been recorded in the area. The growing season is usually more than 180 days except in the higher places like South Mountain.

Drainage. The area is drained by the Delaware and Susquehanna rivers and their tributaries except for parts of Adams and Franklin counties where the streams are tributaries of the Potomac River. The Susquehanna and Delaware rivers and their larger tributaries, such as the Schuylkill and Lehigh rivers and Swatara Creek, all rise on the north side of Kittatinny, Blue or North Mountain and flow in a generally southeasterly direction across the region with little regard for geologic structure. The drainage of the limestone valley is largely underground and large streams are lacking except in Northampton County where the Lehigh River flows northeastward to join the Delaware River.

Physiography. Parts of four physiographic provinces are present: the Coastal Plain, Piedmont, Blue Ridge, and Valley and Ridge. They all have a general northeast-southwest trend. The Blue Ridge Province includes the two divisions of the Appalachian Mountains, the Jersey Highlands, and the Blue Ridge Province. The two provinces are separated from each other by a 50 mile break which extends from the Penn and Neversink Mountains at Reading to the South Mountain south of Carlisle, with the exception of an isolated group of hills southwest of Reading. The Valley and Ridge includes the great limestone valley which extends in a sweeping curve from Franklin County on the Maryland state line to Northampton County on the Delaware River. The Piedmont Province lies southeast of the Blue Ridge Province. It includes the areas underlain by old metamorphic rocks and the Triassic sediments. The Coastal Plain Province is a narrow strip of Cretaceous and later unconsolidated sediments along Delaware River south of Morrisville. Erosion surfaces are conspicuous in many parts of the area. The Kittatinny, Schooley, and Harrisburg peneplanes are present and terraces such as the Bryn Mawr, Brandywine, Sunderland, Wicomico, and Talbot have been recognized.

Geologic history. The geologic history of the region begins in Archean time with the formation of the Baltimore gneiss, the basement rock of the region. Upon this rock were deposited in Algonkian time the Glenarm series composed of several formations including marble, schist, slate, and conglomerate. These rocks are evidently of sedimentary origin but they have been thoroughly metamorphosed and intruded by igneous rocks. Some of the metamorphism and most of the intrusion took place in pre-Cambrian time although some of the metamorphism and some of the intrusive rocks are later. The early intrusives were granite, quartz monzonite, quartz diorite, granodiorite, anorthosite, gabbro, pyroxenite and peridotite. The last two are now largely

altered to serpentine. Some of the other igneous rocks have been metamorphosed but in a lesser degree. During the Cambrian and Ordovician times sediments consisting of sand, clay, and calcareous material were deposited. Just how much material was deposited from Ordovician time to the close of the Paleozoic can not be determined. Deposits of Paleozoic age younger than Silurian are lacking in this area. At the close of the Paleozoic era the rocks were folded and the area was uplifted. Apparently, the area was land during part of the Triassic time and during this period the Triassic sediments were laid down in an elongated trough which extends across the State. During Jurassic and part of Cretaceous time the area was undergoing erosion. During Cretaceous and later periods sediments were laid down in the region adjacent to Delaware River. The rest of the area was undergoing erosion. There have been long periods of erosion with the development of peneplanes and terraces and interrupted by periods of uplift with renewed stream action. During Pleistocene times, the ice sheets invaded the northern part of the area upon several occasions. They deposited the moraines so conspicuous in Northampton County. After the retreat of the ice, the southeastern part of the region was depressed.

Geologic structure. The geologic structure is complex except in the belt of Triassic rocks and in the Coastal Plain. The Paleozic and pre-Cambrian rocks are folded and faulted. Overthrust and normal faults are numerous. The most important of the former is the Martic overthrust fault. Folding is conspicuous in the Paleozoic rocks and in the crumpled rocks of the Piedmont. Folding and faulting together with subsequent erosion has exposed the rocks in such a way that they can be grouped in three belts, the Cambrian and Ordovician limestones and shales of the valleys, the pre-Cambrian and Lower Cambrian sandy sediments, and the sandstones and shales. The narrow strip of coastal plain sediments which rest on the pre-Cambrian rocks is not sufficiently important to be considered a fourth belt. Geologic structure is a controlling factor in the occurrence of ground water. Due to folding and faulting and subsequent erosion the rocks are greatly disturbed. The major features developed the belts of rock mentioned above which show very different water-bearing characteristics. The minor structural features control the local occurrence of ground water. The structure of the region is not favorable for flowing wells and there are no large artesian basins, but a few wells overflow. Fault, bedding, joint, schistosity, cleavage, and fracture planes exert a great influence on the occurrence of ground water. Wells located without regard for these factors may be failures.

Rock formations and their water-bearing properties. The rock formations from the Baltimore gneiss, of Archean age, to the unconsolidated terrace deposits of Quaternary age, are described and their water-bearing properties discussed. The igneous rocks—granite, granodiorite, quartz diorite, quartz monzonite, anorthosite, gabbro and diabase—are poor aquifers and few wells drilled in them yield large supplies. The pre-Cambrian rocks usually yield small supplies but a few wells yield more than 100 gallons per minute. Both igneous and metamorphic rocks are impervious but due to openings such as joint, schistosity, and fault planes they contain considerable volumes of ground water. Many wells obtain the major portion of their supply at or near the contact of disintegrated and fresh rock. The sandy Lower Cambrian formations resemble the pre-Cambrian metamorphic rocks in their water-bearing properties. The quartzites yield small supplies of water very low in total dissolved solids. Due to the impervious nature of these rocks and the importance of openings as ground water storage space, wells should not be drilled to great depths. In general openings decrease in depth and the chances for successful completion of the well are diminished. Few wells obtain large supplies at depths exceeding 300 feet.

The pre-Cambrian marbles are similar to the Paleozoic limestones in water-bearing properties. Marble and limestone are impervious but due to their solubility in water containing carbon dioxide they frequently contain solution channels. Some of these channels contain ground water derived largely from surface drainage through sink holes. Wells which intersect such water-filled channels yield large supplies, but wells which do not intersect them are often failures or yield small supplies. In general the purer limestones are the most soluble and consequently contain more solution channels and are more favorable groundwater horizons. All the large springs issue from limestone. The shales are poor water-bearing formations and few wells in them yield large

supplies. Where the shale is metamorphosed to slate some wells yield large supplies. In the areas underlain by limestone and calcareous shale most people store rain water for use in laundry work. Some people who dwell on the limestone areas are fortunate enough to own springs which issue from the sandstones and quartzites on the adjacent mountains. They pipe them to their homes and have a supply of soft water under pressure. Some municipalities do the same thing. Few deep wells in the limestone have been successful except in Lehigh and Northampton counties. In general, most wells in the limestone obtain their supplies of water at depths of less than 300 feet.

The Triassic deposits consist of sandstones, shales, and conglomerates, the predominating color of which is red. These rocks are the best aquifers in the area except the Patapsco, of the Cretaceous system, and fewer failures to obtain water are reported than in the other belts. Domestic supplies are usually obtainable at depths of less than 300 feet. Many of the wells that produce more than 100 g.p.m. are about 500 feet deep. The unconsolidated sand and gravel of the Coastal Plain are excellent aquifers but in most places they are too thin to be of importance as sources of ground water. In the lower end of Philadelphia they yield large supplies of water used in a variety of industries.

Mineral matter dissolved in water. Altogether 144 samples of water from wells and springs were collected and analyzed in the water resources laboratory of the United States Geological Survey. Of the 144 samples only two contained more than 1000 parts total dissolved solids per million parts of water and only 10 contained 500 parts per million; and 46 contained less than 100 parts per million. The largest amounts of solids were found generally in the waters from the limestones and from the shales and sandstones of Triassic age. None of the samples analyzed contained enough dissolved mineral matter to be unsatisfactory for drinking or cooking purposes. Many of the waters are hard due to the presence of the bicarbonates of calcium and magnesium, which are largely removed by boiling. The waters from the quartzites are very soft.

Utilization of ground water. The uses of ground water are many but they can be grouped into (1) private supplies for domestic use, (2) supplies for livestock, (3) supplies for industrial use including, (4) railroad supplies, and (5) supplies for public water works. Most wells in the area are for private supplies for domestic use. A number of wells furnish water at barns, particularly on the large dairy farms. The use of wells for industrial purposes is increasing. The constant temperature of the water is most valuable for cooling. The railroads in this area have some wells but they rely chiefly upon surface supplies. A number of towns and villages in the area use ground water. They have either springs or wells or in some cases both. The towns located in the Triassic belt are largely dependent on wells. Very few of them obtain water from surface supplies.

Recovery of ground water. Ground water is largely recovered by springs and wells. The common types of wells are dug and drilled. The latter are decidedly the more popular at present; but many old dug wells are still in use. Some springs have been in use for a hundred or more years.

Ground water by counties. The geology and ground water properties of the formations are discussed by counties with data by townships. Each county has a table of well data. A table of water analyses is included at the end of the report.

GROUND WATER IN SOUTHEASTERN PENNSYLVANIA

BY GEORGE M. HALL

INTRODUCTION

AREA COVERED

The area covered in this report includes that portion of Pennsylvania lying south and east of Kittatinny, Blue, or North Mountain. See Figure 1. It includes an area of approximately 8,000 square miles which

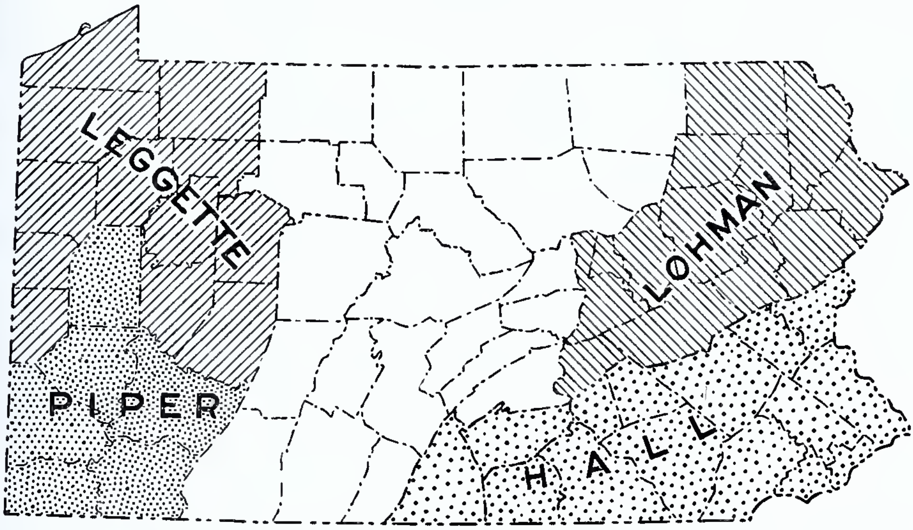


Figure 1. Map of Pennsylvania showing area covered by this report and progress of ground-water surveys. Report by A. M. Piper, bulletin W1 of the Pennsylvania Topographic and Geologic Survey, 1933. Reports in preparation by R. M. Leggette and S. W. Lohman.

is divided into 15 counties, 13 of which lie wholly within the area described. The area contains Philadelphia, the largest city in Pennsylvania, and also other large and prosperous cities, such as Harrisburg, the State Capital, Reading, York, Lancaster, Allentown, Bethlehem, Easton, Chester, and many towns and villages. Part of the region is, however, distinctly rural and includes localities that are thinly settled. The total population of the area described in this report exceeds 4,000,000.

The field work on which this report is based was done by the writer in the summer of 1925. A brief trip was made in August, 1927, to collect additional samples of water from several wells and springs sampled during the field season of 1925. Another brief trip was made during June, 1931, when some additional data were obtained on wells drilled in northern Chester County. It is one unit of a project undertaken by the Pennsylvania Topographic and Geologic Survey, in cooperation with the United States Geological Survey, for a survey of the entire State with respect to the occurrence, quantity, head, and quality of its ground-water supplies and of the best methods for re-

covering and utilizing these water supplies for domestic and industrial uses. The investigation was conducted under the supervision of O. E. Meinzer, geologist in charge of the division of ground water in the U. S. Geological Survey.

SOURCES OF GEOLOGIC INFORMATION

The area covered by this report is one of complicated geology. It contains many rock formations, which differ widely in origin, character, and age. The oldest of these formations have been extensively folded, faulted, overthrust, and intruded by igneous magmas of various composition and age. Moreover, the rocks have in large part been so radically altered by metamorphic processes that their original character is greatly obscured. Obviously it would have been quite impossible to make even a general survey of the ground waters of this area in a single season of field work if the geology of the area had not already been extensively studied and accurately mapped. The area was covered by the Second Geological Survey of Pennsylvania, which in 1893 published a geologic map of the area that has served as the basis for later work. More recently detailed geologic study has been given to different parts of the area, especially by the Misses F. Bascom and A. I. Jonas, Mrs. E. B. Knopf, and by G. W. Stose and B. L. Miller. The results of much of this work have been published, as is shown in the following list, and were therefore available for use in connection with the ground-water investigation. A geologic map of the area, based on all the published and unpublished work, has been prepared by Stose and Jonas, as a part of the new geologic map of the entire State. The southeastern part of the State map is published in the present report as Plate 1, and the formational names used in this report agree with the legend on the plate.

In the course of the field work the writer endeavored to familiarize himself with the geology as it is described in the published reports and is shown on maps in these reports or on the geologic map of the Second Pennsylvania Survey. Fortunately he was already familiar, through work in previous years, with much of the geologic section exposed in the area. Later the new geologic map was generously made available and was used in the preparation of this report.

The following is a list of the principal geologic publications that were consulted in the preparation of this report:

Second Geological Survey of Pennsylvania.

- Report of progress C, York and Adams counties, 1876.
- Report of progress C2, York and Adams counties, 1877.
- Report of progress C3, Lancaster County, 1880.
- Report of progress C4, Chester County, 1883.
- Report of progress C5, Delaware County, 1885.
- Report of progress C6, Philadelphia and the southern parts of Montgomery and Bucks counties, 1882.
- Report of progress D3, vol. I, Lehigh and Northampton counties, 1883.
- Report of progress D3, vol. II, Berks County, 1883.
- Report of progress D5, Atlas of colored geological county maps of Cumberland, Franklin, and Adams counties.
- Report of progress Z, Terminal moraine in Pennsylvania and western New York, 1884.

Williams, G. H., The volcanic rocks of South Mountain in Pennsylvania and Maryland: Am. Jour. Sci., 3d ser., vol. 44, pp. 482-496, 1892.

Bascom, F., The ancient volcanic rocks of South Mountain, Pennsylvania: U. S. Geol. Survey Bull. 136, 1896.

Walcott, C. D., The Cambrian rocks of Pennsylvania: U. S. Geol. Survey Bull. 134, 1896.

Bascom, F., Water resources of the Philadelphia district: U. S. Geol. Survey Water Supply Paper 106, 1904.

Bascom, F. and others, U. S. Geol. Survey Geol. Atlas, Philadelphia folio (No. 162), 1909.

Bascom, F. and others, U. S. Geol. Survey Geol. Atlas, Trenton folio (No. 167), 1909.

Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

Jandorf, M. L., Preliminary report on the York Valley limestone belt: Pennsylvania Top. and Geol. Survey Comm., 1910-1912, pp. 50-129, 1912.

Miller, B. L., Graphite deposits of Pennsylvania: Pennsylvania Top. and Geol. Survey Comm., Report 6, 1912.

Brown, T. C., Notes on the origin of certain Paleozoic sediments: Jour. Geology, vol. 21, pp. 233-244, 1913.

Bliss, E. F. and Jonas, A. I., Relation of the Wissahickon mica gneiss to the Shenandoah limestone and Octararo schist of the Doe Run and Avondale region, Chester County, Pennsylvania: U. S. Geol. Survey Prof. Paper 98, pp. 9-35, 1916.

Bassler, R. S., Cambrian and Ordovician: Maryland Geol. Survey, 1919.

Bascom, F. and Miller, B. L., U. S. Geol. Survey Geol. Atlas, Elkton-Wilmington folio (No. 211), 1920.

Bascom, F., Cycles of erosion in the Piedmont province of Pennsylvania: Jour. Geology, vol. 29, no. 6, pp. 540-559, 25 figs., September-October, 1921.

Knopf, E. B., Chrome ores of southeastern Pennsylvania and Maryland. U. S. Geol. Survey Bull. 725, pp. 85-99, 1 fig., August 4, 1921.

Stose, G. W. and Jonas, A. I., The lower Paleozoic section of southeastern Pennsylvania; Washington Acad. Sci. Jour., vol. 12, no. 15, 1922.

Jonas, A. I., Rocks of the Quarryville quadrangle: Pennsylvania Top. and Geol. Survey Bull. No. 75, 1923.

Knopf, E. B. and Jonas, A. I., Stratigraphy of the crystalline schists of Pennsylvania and Maryland: Am. Jour. Sci., 5th ser., vol. 5, pp. 40-62, 1923.

Stose, G. W. and Jonas, A. I., Ordovician overlap in the Piedmont Province of Pennsylvania and Maryland: Geol. Soc. America Bull., vol. 34, pp. 507-524, September, 1923.

Grabau, A. W., Principles of stratigraphy, pp. 530, 784, New York, 1924.

Stose, G. W., New type of structure in the Appalachians: Geol. Soc. America Bull., vol. 35, no. 3, pp. 465-480, 8 figs., Sept. 30, 1924; abstract (with discussion by W. H. Hobbs, E. T. Wherry, A. C. Lawson, A. I. Jonas and A. C. Spencer) no. 1, pp. 63-64, March 30, 1924.

Phemister, T. C., A note on the Lancaster Gap Mine, Pennsylvania: Jour. Geology, vol. 32, no. 6, pp. 498-510, 8 figs., August-September, 1924.

Bascom, F., The resuscitation of the term Bryn Mawr gravel: U. S. Geol. Survey Prof. Paper 132, pp. 117-119, November 12, 1924.

Miller, B. L., Allentown quadrangle, Atlas No. 206, Pennsylvania Top. and Geol. Survey, 1925.

Stose, G. W., Mineral resources of Adams County, Pennsylvania: Pennsylvania Top. and Geol. Survey, 4th ser., Bull. Cl, pt. 2, 64 pp., 1 fig., 11 pls. (incl. map), 1925.

Miller, B. L., Limestone of Pennsylvania: Pennsylvania Top. and Geol. Survey, 4 ser., Bull. M7, pp. 352, 15 pls. (incl. map), 7 figs. 1925.

Jonas, A. I. and Stose, G. W., New Holland Quadrangle, Atlas no. 178, Pennsylvania Top. and Geol. Survey, 1926.

Behre, C. H., Jr., Observations on structures in the slates of Northampton County, Pennsylvania: Jour. Geology, vol. 34, no. 6, pp. 481-506, 19 figs., August-September, 1926.

Behre, C. H., Jr., Slate in Northampton County, Pennsylvania: Pennsylvania Top. and Geol. Survey, 4 ser., Bull. M9, 308 pp., 39 pls. (incl. maps), 1927.

Behre, C. H., Jr., Geologic factors in the development of the eastern Pennsylvania slate belt: Am. Inst. Min. and Met. Eng. Tech. Pub. no. 66, 17 pp., 12 figs., February, 1928; Trans. vol. 76, pp. 393-412, 12 figs., 1928.

Stose, G. W., and Jonas, A. I., Ordovician shale and associated lava in southeastern Pennsylvania: Geol. Soc. America Bull., vol. 38, no. 3, pp. 505-536, 10 figs., September, 1927.

Stose, G. W., High gravels of Susquehanna River above Columbia, Pennsylvania: Geol. Soc. America Bull., vol. 39, no. 4, pp. 1073-1086, 7 figs., 1 pl., December 30 1928.

Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (no. 225), 1929.

Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry—Quarryville District, Pennsylvania: U. S. Geol. Survey Bull. 799, 1929.

Jonas, A. I. and Stose, G. W., Lancaster Quadrangle, Atlas No. 168, Pennsylvania Top. and Geol. Survey, 1930.

Bascom, F. and others, Geology and mineral resources of the Quakerstown-Doylestown district, Pennsylvania and New Jersey: U. S. Geol. Survey Bull. 828, 1931.

Bascom, F. and Stose, G. W., U. S. Geol. Survey Geol. Atlas, Coatesville-West Chester folio (no. 223), 1932.

Stose, G. W. and Jonas, A. I., Geology and mineral resources of the Middletown Quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, 1933.

SOURCES OF HYDROLOGIC INFORMATION

The present report is based chiefly on the information obtained by the writer during several months of field work in 1925. Information was obtained from well owners, drillers, and other responsible persons, in regard to about 1,300 wells throughout the area. So far as practicable, these wells were located and the rock formations through which they extend were determined in the course of the field work. However, much of the geologic correlation of the wells was necessarily done in the office after the new geologic map became available. Numerous springs were also examined and their geologic relations were studied in the field.

The information that was obtained in regard to the wells is that covered by the well and spring schedules that are used by the Water Resources Branch of the United States Geological Survey in its ground-water investigations. Most of the information that was obtained in regard to wells is given in the tables at the ends of the several county reports, and most of the spring data are to be found in the text of the county reports. The well data, as published, doubtless contain many inaccuracies, which, in the nature of the case, is unavoidable, especially in a general ground-water survey in which time is not available to make measurements and tests of the wells. It is believed, however, that the information given is essentially reliable and that the generalizations regarding the water-bearing properties and well prospects of the different formations are sound.

The depths of the wells, the depths to the water levels in the wells, and the yields of the wells are, as a rule, those reported by informants who were interviewed, in some cases from written records but often from memory. A small reported yield—one of less than 5 gallons a minute—is likely to represent the total production of the well

that it is practicable to obtain even with great drawdown or by lowering the water level virtually to the bottom of the well. It is generally based on a bailing test made at the time the well was finished or on the maximum rate of pumping that was found to be practicable after the well was put into service. A large reported yield, such as is required for an industrial plant or a system of public water works, is generally fairly accurate, being based on the rated capacity of the pump, on the time required to raise the water level a certain height in a storage tank of known dimensions, or on accurate measurements of pumpage with a weir or meter. In regard to some wells the drawdown with a measured rate of pumping has also been determined, so that the specific capacity of the well is known. The information in regard to the wells of intermediate yield, such as 5 or 10 gallons a minute, is, on the whole, the least accurate. These wells are commonly used for domestic or live-stock supplies, and all that is known in regard to many of them is that they furnish unfailing supplies at the moderate rate of pumping to which they are subjected. In regard to many of them there is no reliable information as to drawdown, and some of them may be strong wells that would stand the test of heavier pumping.

In the course of the field work, samples of water were collected from 144 wells or springs in the area, care being taken to obtain a group of samples from each section of the area and from each important water-bearing formation or group of formations. These samples were analyzed by Margaret D. Foster and Charles S. Howard in the water resources laboratory in Washington, D. C., according to the standard methods of the United States Geological Survey. The analyses are tabulated at the end of the report and are discussed, especially with reference to the geological sources of the water, on pages as shown in the index.

The statistical study of the well records with reference to depth and yield and the relation of yield to depth in each of the principal kinds of rock was made by R. M. Leggette, who prepared the summary of depth and yield of wells by groups of formations on pages 70-72. The study of the analytical data with reference to the mineral matter dissolved in the waters in the different rock formations was made by O. E. Meinzer who prepared the section entitled "Mineral matter dissolved in the water."

CLIMATE

The greatest climatic variations in the area covered by this report are due to differences in elevation above sea level rather than distance north of the equator. The elevations range from sea level along Delaware River to approximately 2,200 feet in South Mountain while the distance from the southern to the extreme northern limits of area is about 80 miles or slightly more than one degree of latitude. Most of the stations which record data on climate are situated at lower elevations and accurate data on the climate in the higher areas are not available.

The mean annual precipitation is at a maximum in the southeastern part of the area where it is almost 50 inches and at a minimum in the valley area in the southwestern part where it is about 37

inches. The figures for any one year may, however, show considerable deviation from the mean. Snowfall increases to the north and west from the southeastern part of the area. The mean annual snowfall at Philadelphia is approximately 25 inches and increases to about 40 inches in the western part of the area. It is doubtless higher on South Mountain. Precipitation is well distributed throughout the year and droughts of long duration are uncommon. The drought of 1930 was unusually long. Snowfall is generally confined to months from November to April inclusive. The heaviest snowfalls occur generally in late February and in March. Rain falls frequently and thunder showers are frequent during the summer months. Hail storms are not uncommon during the summer.

The mean annual temperature is about 52° with a summer mean of approximately 72 to 73° F. and a winter mean of 30 to 32° F. Days on which temperature rises above 100° F. are not frequent but temperatures as high as 107° and 108° F. have been recorded in the area. Temperatures below zero are not uncommon but some temperatures as low as —40° F. have been recorded.

The growing season is, except at the higher elevations, usually more than 180 days in length and at the lower elevations along the Delaware is more than 200 days. The first killing frosts usually occur in October and the last in April, but in some years they may occur as early as September or as late as May.

The amount and distribution of precipitation is a controlling factor in stream flow and the occurrence of ground water. The precipitation either runs off, soaks into the ground, or evaporates. The percentage of each is dependent upon several factors such as the kind, amount, and distribution of the precipitation, the character of the terrain upon which it falls and the physical condition of the atmosphere after storms. Although, at times, the run-off is high, disastrous floods in the major streams are rare. Large volumes of water soak into the ground to replenish the ground-water supply. Evaporation in a humid region like southeastern Pennsylvania is less than in arid regions and much smaller volume of water evaporates than runs off or percolates into the ground. The run-off ceases soon after a storm or after the melting of snow and ice but the perennial streams are maintained by the discharge of ground water through springs and seepages. The ground water is recoverable by wells which penetrate the water table. In years of insufficient precipitation the volume of ground water is much reduced, stream flow decreases, and wells and springs may go dry. In years of abundant precipitation springs discharge increased volumes and the ground-water level rises in wells.

DRAINAGE

Southeastern Pennsylvania is drained by the Delaware and Susquehanna rivers[1] and their tributaries, with the exception of parts of Adams and Franklin counties where the streams flow to the Potomac River[1]. The major streams, the Delaware and Susquehanna rivers, as well as some of their larger tributaries such as the Lehigh and Schuylkill rivers, rise on the north side of Kittanning or North Mountain

[1] Stream flow data on these rivers and their tributaries have been published by the United States Geological Survey and the Department of Forests and Waters, State of Pennsylvania.

and flow in a generally southeasterly direction across the region with little regard to the geologic structure. The smaller streams, except in the Piedmont Province, are conformable with the underlying structure.

The Great Valley is not drained by a single stream but by the tributaries of the larger streams, Cononcocheague Creek which flows to the Potomac and Conodoguinet Creek, a tributary of the Susquehanna River, draining most of the Great Valley west of Susquehanna River. Lehigh River is the largest stream which follows the valley for any considerable distance. Much of the drainage in the Great Valley flows underground.

All the master streams and their larger tributaries are perennial but the volume of run-off varies from day to day depending upon the season of the year, and other conditions. Many of the smaller tributaries show great fluctuations but as shown on Plate 1 many of them are perennial. In years of normal precipitation these streams are important sources of surface water.

During the last several decades two large hydroelectric plants have been built on Susquehanna River; one at Safe Harbor and the other at Holtwood. These plants supply power not only to cities and towns in southeastern Pennsylvania but also to Baltimore and the surrounding territory in Maryland. During the 19th century canals were built along the larger streams, but most of these canals are abandoned.

Mills driven by water power were erected at many places in the area, some on the larger streams and many on the smaller ones. Today, however, few water-power mills are in operation. Steam engines, internal combustion engines, and electric motors drive the machinery in most of the mills. Many of the old mills are abandoned, particularly in the Piedmont where abandoned mills, dams, and mill races are numerous. During the last decade some of these dams and mill races have been repaired and new overshot wheels have been installed to furnish power for pumping wells. When properly installed, the maintenance cost is small. In many cases these dams, races and wheels add an element of beauty and attraction to the estate as well as furnishing power at low cost for pumping water. Most of the mills were abandoned on account of economic conditions rather than lack of water and anyone contemplating the installation of a water-wheel for pumping water from wells can usually depend upon the stream once used by a mill for water.

PHYSIOGRAPHY

The area described in this report consists of roughly parallel or concentric belts, with general northeast-southwest trends, that form parts of four physiographic provinces. These provinces, named from southeast to northwest, are the Atlantic Coastal Plain Province, the Piedmont Province, the Blue Ridge Province, and the Appalachian Valley and Ridge Province. These provinces are shown on the sketch map (see fig. 2).

Atlantic Coastal Plain. The very small and narrow belt that belongs to the Coastal Plain lies in the southeastern corner of the State along Delaware River. It is crossed by many streams, most of them small, which rise in the Piedmont Province. The beds of unconsoli-

dated or poorly consolidated sediments that underlie the Coastal Plain were once more widespread but have largely been removed from this area by erosion. Except in areas immediately adjacent to Delaware River, the Coastal Plain consists of a series of isolated fragments separated by the streams which have eroded down to the underlying crystalline rocks.

Piedmont Province. The Piedmont Province is an extensive, gently undulating province which in general slopes southeastward. It has undergone prolonged erosion so that much of its former plateau-like

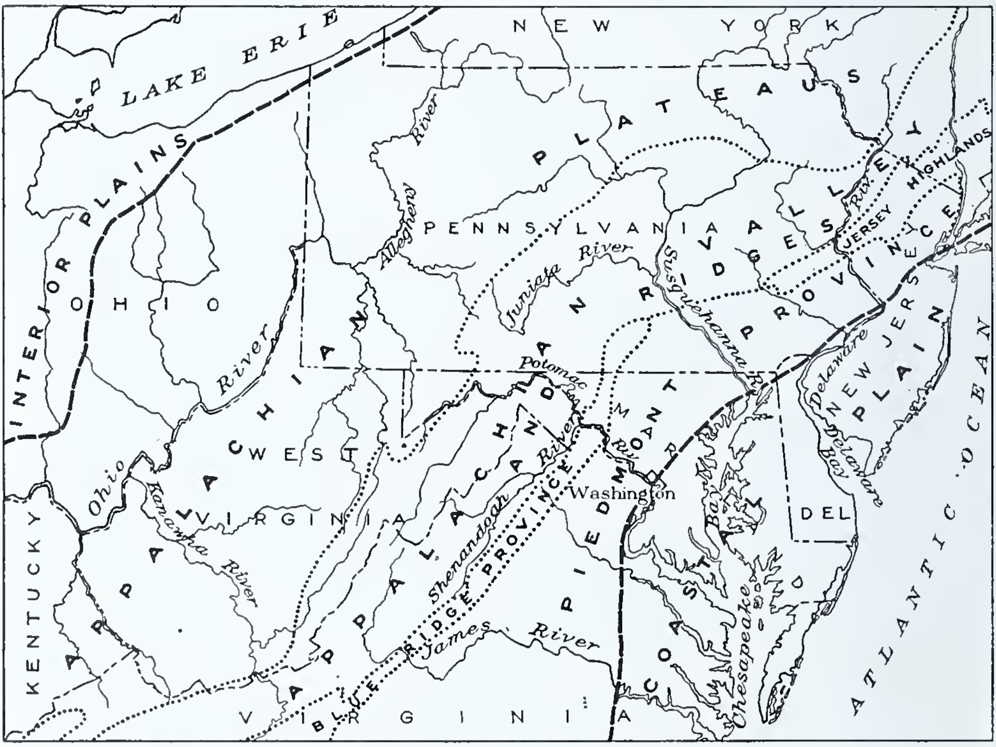


Figure 2. Physiographic provinces in the Middle Atlantic States. The Jersey Highlands, including the Reading and Durham Hills, are the northern representative of the Blue Ridge province and are generally considered to extend northward into the New England upland. South Mountain in Pennsylvania forms the north end of the Blue Ridge province. (After Knopf and Jonas.)

appearance has been modified to slopes and gently rounded hills. It comprises a southeastern belt, adjacent to the Coastal Plain, which is underlain chiefly by pre-Cambrian crystalline rocks but in some places by Ordovician limestone, and a northwestern belt which is underlain chiefly by Triassic sandstone, shale, and trap rock or diabase. Ridges of Cambrian quartzite are found in both of these belts. The deposits of the Coastal Plain once extended much farther inland over the crystalline rocks of the Piedmont Province, as shown by the isolated areas of such materials which have escaped erosion. The Triassic rocks are predominately red sediments, the softer of which are eroded to lowlands. Triassic quartzose conglomerates, Cambrian quartzite, and the diabase form ridges which extend across these lowlands. Indeed, the belt underlain by the Triassic rocks is so different from the rest of the

Piedmont Province that it might be considered a separate physiographic division.

The Blue Ridge Province. The Blue Ridge Province includes the two divisions of the Appalachian Mountains present in Pennsylvania, the Blue Ridge Province, and the Jersey Highlands. The Appalachian Mountains extend from western Massachusetts to Georgia with a topographic break in Pennsylvania of approximately 50 miles which separates them into a northern and a southern division. The Jersey Highlands which extend from New Jersey across Delaware River into Pennsylvania at Easton include the Reading and Durham Hills. These hills or mountains, as they are often called, rise to 1100 or 1200 feet. With the exception of an isolated group of hills in Berks and Lebanon counties about 6 miles southwest of Reading, the Jersey Highlands terminate abruptly at Schuylkill River in Penn and Neversink mountains. The topographic break between the two divisions extends from Schuylkill River to South Mountain south of Carlisle and the sharp division between the Piedmont and Appalachian Valley and Ridge Provinces is lacking. The southern division of the Appalachians, of which South Mountain in Adams, Franklin, and Cumberland counties is the northern end, is known as the Blue Ridge Province. The province is named after the Blue Ridge in Virginia, and not from the Blue Mountain on the north side of the Cumberland-Lebanon Valley in Pennsylvania. South Mountain is much loftier and more massive than the Durham and Reading Hills, and rises to elevations of about 2200 feet.

The oldest rocks of sedimentary origin in the Reading and Durham Hills are the graphite-bearing, biotile gneisses which contain intercalated layers of marble and quartzite. These rocks have been invaded by igneous rocks of various kinds. The igneous activity was accompanied by considerable metamorphism and some mineralization. Both the igneous and sedimentary rocks, except the dikes of Triassic diabase, are overlain unconformably by early Paleozoic sediments. South Mountain consists of a core of pre-Cambrian devitrified rhyolite and epidotized basalt flows, mostly in western Adams County. The igneous rocks are overlain unconformably by sedimentary rocks, chiefly sandstones and shales of Cambrian age, which are altered, in part, to quartzite and phyllites.

Appalachian Valley and Ridge Province. The Appalachian Valley and Ridge Province lies northwest of the Piedmont Province and is in part separated from it by the Blue Ridge Province. The only part of this province that is covered by this report is the southeastern part, the so-called Great Valley. It lies southeast of Kittatinny, North or Blue Mountain, the first of the valley ridges. The Great Valley extends through southeastern Pennsylvania without interruption from Delaware River to the Maryland-Pennsylvania line. It parallels Blue Mountain but varies greatly in width from place to place. It is underlain by calcareous deposits of Cambrian and Ordovician age, which have been eroded more rapidly than the siliceous formations that form the mountains on the sides of the valley. The main drainage lines extend across the valley, except in the extreme western part of the

area. Surface streams are not numerous and many of the secondary drainage courses are below the surface.

Relatively level uplands occur at various elevations in all of these provinces. The areal extent of these uplands is variable, and some are gravel-covered while others are not. Erosion has attacked some more rapidly than others. The presence of these uplands has influenced the settlement of the region and the life of the inhabitants. Many papers on this region discuss these uplands. The most detailed discussions are to be found in the publications of Stose[1], Bascom[2 4], Knopf[3] and Jonas[3]. The following table combines the work of these authors.

These uplands have been cut by streams or by waves. All but the several lower terraces are stream-cut. During the period subsequent to the formation of great mountains by folding of the crust at the close of the Paleozoic era, erosion reduced the mountains to lowlands and the whole surface to a peneplane. At later times this oldest peneplane, the Kittatinny, was uplifted. Erosion attacked the elevated plain but before all trace of the Kittatinny surface was destroyed a new uplift renewed the power of the streams to erode and left remnants of the Kittatinny and the partly completed Schooley peneplane. Each successive uplift left a partly completed peneplane and accelerated erosion which immediately attacked the areas previously leveled. These peneplanes are now preserved chiefly in those places where the rocks are most resistant to erosion. The total areal extent of the higher ones in the region covered by this report is very small. In fact, the old surface is preserved in the flat tops of the higher mountains and hills. All of the peneplanes and terraces slope from the northwest to the southeast.

Summary. For the purposes of this report the area covered can for the most part be divided into three belts—the belt of pre-Cambrian and Cambrian crystalline rocks in the Piedmont and Blue Ridge provinces, the belt of Triassic rocks in the Piedmont Province and the belt of Cambrian and Ordovician limestone and shale in the Great Valley, a part of the Appalachian Valley and Ridge Province. As already stated, other extensive areas of limestone lie in the Piedmont provinces, the belt of Triassic rocks in the Piedmont Province and with the geology of these belts that reference will constantly be made to them.

GEOLOGIC HISTORY

The geologic history of the area begins far back in pre-Cambrian time with deposition of the sediments that have formed the Baltimore gneiss and other biotite gneiss, which is the basement rock of the area, and considered to be of Archean age. This rock is sedimentary in origin but recrystallization due to metamorphism has almost obliterated all traces of its original character. The bottom of the gneiss

[1] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), pp. 16-17, 1909.

[2] Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), pp. 16-17, 1929.

[3] Knopf, E. B. and Jonas, A. I., Geology of the McCalls Ferry-Quarryville District, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 91-98, 1929.

[4] Bascom, F., The resuscitation of the term Bryn Mawr gravel: U. S. Geol. Survey Prof. Paper 132, pp. 117-119, 1924.

Altitude, in feet, of base-levels and erosion surfaces in Appalachian region

Peneplanes in Fairfield-Gettysburg Area[d]		Piedmont province of Pennsylvania (F. Bascom)			Remnants of erosion surfaces established by Eleanora B. Knopf[c]					
		Peneplanes	West	East		Pocono Mountain	Blue Mountain and vicinity	South Mountain	Welsh Mountain and vicinity	Mine Ridge southward to sea level
Kittatinny	1,900	Kittatinny	1,800	1,600–1,100	Kittatinny	1,800	1,660	1,340		
Weverton	1,400	Schooley	1,300	1,000–900	Schooley		1,400–1,300	1,180–1,100	1,080	
					Mine Ridge		1,100–1,000	1,000	940	880–820
		Honeybrook	860	800–700	Honeybrook		900–840	840–800	800–720	720
Harrisburg	620	Harrisburg	800	500	Harrisburg		700–600		620	620
		Early Brandywine[a]	500	400–390	Bryn Mawr		560–500			500–460
		Terraces								
		Late Brandywine[b]	400	300–200	Brandywine		440–400		420	320
		Sunderland	300	180–100	Sunderland					200–100
		Wicomico	90	45	Wicomico					80–60
		Talbot	45	40–0	Talbot					40

[a] Now replaced by Bryn Mawr. Bascom, F., Resuscitation of the term Bryn Mawr gravel: U. S. Geol. Survey Prof. Paper 132, pp. 117–119, 1924
[b] Now replaced by Brandywine. Idem.
[c] Knopf, E. B. and Jones, A. I., Geology of the McCalls Ferry-Quarryville district, Pennsylvania: U. S. Geol. Survey Bulletin 799 p. 99, 1929.
[d] Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), 1929.

has never been seen and consequently its thickness and the possible sources of the sediments of which it was formed are unknown.

In pre-Cambrian time there were laid down the deposits that have formed the Baltimore gneiss, Franklin limestone, Setters formation, Cockeysville marble, Wissahickon formation, Peters Creek schist, Cardiff conglomerate, and Peach Bottom slate. Into these sediments, which underwent profound folding and erosion, were intruded various igneous masses which range from rocks high in silica to those low in that material and the sediments were highly metamorphosed. Many of these intruded rocks also suffered severe metamorphism. During pre-Cambrian time there was great igneous activity in the area now known as South Mountain, as shown by the volcanic rocks which are exposed in that area.

During late pre-Cambrian time the region underwent profound erosion, and when the Cambrian seas advanced across the bevelled edges of the pre-Cambrian crystalline rocks, they laid down a series of sands and muds which are now known as the Loudoun formation, Weverton sandstone, Chickies quartzite (including the Hellam conglomerate member at base), Harpers formation, and Antietam sandstone, which have in many places been metamorphosed into quartzites, phyllites, and schists. These hard rocks form several small groups of mountains of which South Mountain in southern Pennsylvania is the largest and highest.

The sources of these coarse sediments were eroded, and the seas in later Cambrian time and in the Ordovician period were most of the time clear and abounded in lime-secreting organisms which supplied the materal for enormous thicknesses of limestone. During late Ordovician time, due doubtless to uplift of the adjacent land masses, the Ordovician seas received much mud which, in its present form, is known as the Martinsburg shale. Near Delaware River these beds are metamorphosed into slate. Overlying the black shales and slates of this formation are the red beds of the Juniata formation. They are shown on Plate 1 as either Ordovician or Silurian.

During the rest of the Paleozoic era (the Silurian, Devonian, and the Carboniferous periods) a great thickness of sediments was deposited in the region to the north and west but such sediments as were deposited in this area have been almost completely removed. The folding and faulting so conspicuous in the Cambrian and Ordovician rocks is known to have occurred near the end of the Paleozoic era and before the deposition of the Triassic sediments, which are distinctly not involved in the pronounced folding of the Paleozoic rocks.

During Triassic times materials eroded from the highlands which existed at that time to the south and east were deposited in elongated troughs. Later, uplifting along the faults which formed the northern and western boundaries of the troughs produced uplands which yielded a smaller volume of sediments. The troughs deepened progressively to the westward and a total thickness of probably 25,000 feet of sediments, chiefly sandstones, shales, and conglomerates, accumulated in them. However, due to the continuous advance of the center of sedimentation to the westward, it is improbable that more than half the total thickness is present at any one locality.

During the closing part of this period the sedimentary rocks were

intruded by dikes and sills of diabase, an igneous rock. Narrow dikes also cut rocks of much greater age.

The Triassic deposition was followed by a prolonged period of erosion which extended through Jurassic and into Cretaceous time, and resulted in the reduction of the region to a nearly level plain near sea level.

In the Cretaceous period and in the subsequent Tertiary period, beds consisting chiefly of sand and clay, swept from the uplifted region to the west, were deposited throughout the Coastal Plain Province and over the southeastern corner of the area covered in this report. These deposits are very thin in this area except in the southern part of Philadelphia. In the Pleistocene epoch the continental ice sheet advanced several times from the north but did not invade much of this area. Quaternary terraces were formed at this time along the longer streams and covered with gravel. Subsequent to the retreat of the last ice sheet there has been a slight depression of the region with a partial flooding of the Coastal Plain Province.

GEOLOGIC STRUCTURE

The geologic structure of the area covered in this report is shown in part on Plate 1. The structure is very complex except in the Coastal Plain, where it is simple, and in the belt of Triassic rocks, where it is only moderately complex. The Paleozoic and pre-Paleozoic rocks are greatly folded and faulted, the structure of the oldest rocks being in general the most complicated. Overthrust faults have greatly increased the difficulty of unravelling the structure. The easternmost of these faults shown on Plate 1 is the Martic overthrust fault[1], which extends as a part of a major fracture that can be traced across the southeastern part of Pennsylvania from the Delaware at Morrisville across the Maryland State line south of Hanover. The fracture east of Schuylkill River consists not of a single overthrust fault but of a group of overthrust faults of different lengths, roughly parallel in their general trend. The dips of the fault planes are low.

In general, only pre-Cambrian rocks are included in the movements but in southern York County the overlying Cambrian beds have taken part in the movement. The displacement of the beds has been to the northwest but the exact distance has not been determined, and may never be because erosion has removed the edge of the overthrust block. The maximum displacement that has been determined is 11 miles, along Susquehanna River.

Other overthrust faults are shown in the structure section in Plate 1. It has been suggested that the zone of thrusting moved progressively westward and that the faults are younger to the west. There is probably a thrust fault on the west side of the Pigeon Hills in Adams and York counties. Thrust faults of large displacement are recognized on the west side of South Mountain and North Mountain.

Normal faults with the dip of the fault planes almost vertical are conspicuous in the section mentioned. The west side of the Hanover Valley is bounded by one. The west side of the trough in which the Triassic sediments were deposited is formed by another. The depres-

[1] Knopf, E. B. and Jonas, A. I., Geology of the McCalls Ferry-Quarryville District, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 74-75, 1929.

sion formed by the downward movement on the eastern side of this fault affords the elongated basin which continuously deepened toward the border and resulted in the sediments showing an increasingly steeper dip from the eastern to the western side of the trough. Upward movements on the western side of the fault produced the highlands that yielded the material for the quartzose and limestone conglomerates, so conspicuous on the western and northern sides of the trough. Another nearly vertical normal fault to the west has further complicated the structure of South Mountain.

A number of normal faults are shown on Plate 1. Some of them are parallel to the Appalachian folds and others cut across them. They produce an intricate pattern and bring into contact rocks of very different ages. Stose[1] has discussed these faults.

The cross section on Plate 1 shows how the rocks have been deformed. The pre-Cambrian and Paleozoic rocks have been greatly deformed, the former even more than the latter. The folding of some of the pre-Cambrian rocks is most complicated, so complicated that it is almost impossible to show all folding and crumpling on drawings made on a scale suitable for this report. The folding in the Great Valley is less tight and compressed but more complicated than the cross section shows. The numerous minor folds could not be shown on the scale used in this drawing.

The Triassic rocks except the conglomerates dip toward the west and north and increase gradually toward the west and north side of the trough. These beds were laid down subsequent to the general folding and were deposited in a trough formed by the normal fault shown in the cross section on Plate 1 and discussed above. The tilting is due largely to movements along this and similar faults.

The rocks in the eastern part of the Piedmont Province were bevelled and tilted southeastward and in Cretaceous times the sea transgressed and deposited beds of sand and clay. The tilting continued and successive layers were laid down at subsequent times. These rocks all dip gently to the southeast.

OCCURRENCE OF GROUND WATER IN RELATION TO GEOLOGIC STRUCTURE.

The geologic structure of southeastern Pennsylvania is one of the major factors controlling the occurrence of ground water. Folding and faulting together with uplift and erosion have brought to the surface the rocks which form the three belts into which the area is divided. The very large displacements which have occurred along the major faults have restricted the circulation of ground waters in this area. Due to the faulting and folding, rocks which might be good aquifers over large areas have been removed by erosion or are so deeply buried that they are not easily accessible. The Weverton sandstone, which might have been a fairly good water-bearing horizon over a large area, is found in the South Mountain but it is cut off by faults on the east and south sides and north and west of them lies so deeply buried beneath the limestones that the cost of drilling into it is prohibitive. Solution channels in the limestones and marbles are con-

[1] Stose, G. W., New type of structure in the Appalachians: Geol. Soc. America Bull., vol. 35, pp. 465-480, 1924.

trolled in part by the geologic structure and in part by other factors. These channels permit a fairly widespread circulation but folding and faulting frequently confine them to limited areas. Most of these channels lie above the level of the major streams and their larger tributaries. In most instances the channels permit the circulation of ground water in inter-stream areas.

The structure in the area underlain by Triassic rocks is favorable for a widespread circulation and, in places, such a circulation doubtless exists; but the character of the sediments is not equally favorable. The rapid change in character of the sediments along the strike and dip where sandstones are replaced by impervious shales, and the presence of shales and shaley sandstones are not favorable for a widespread circulation of ground water. The presence of well developed joints and bedding planes in the Triassic rocks is favorable to the circulation of ground water. The structure of the coastal plain sediments, a series of gently sloping beds which rest upon the eroded basement of pre-Cambrian rock, is highly favorable to a widespread circulation. The alternating beds of unconsolidated sands and clays form excellent horizons for a widespread circulation; but, except in lower Philadelphia, they are too thin to be valuable as sources of ground water.

Not only do the major elements of the geologic structure influence the occurrence of ground water but the minor features are, equally, or possibly, more important. The minor features exert a great influence locally upon the occurrence of ground water. Many failures to obtain adequate supplies of water are due to locating the well in a structurally unfavorable situation.

The numerous igneous masses intruded into the sedimentary and metamorphic rocks undoubtedly affect the circulation of ground water in the intruded rocks; but due to lack of data the extent of the interference could not be determined in most instances. Springs frequently occur in the vicinity of intrusive masses.

In hilly localities underlain by schist or gneiss, wells should be located so as to take advantage of the accumulation and circulation of the ground water, as shown in Figure 3. In this figure, well A has a very small collecting area and water that seeps into the ground

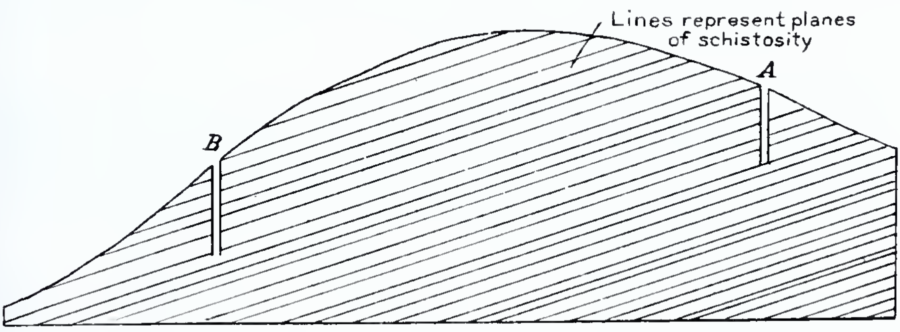


Figure 3. Diagram showing importance of planes of schistosity in the yields of wells drilled in schist and gneiss. Well at A may be a failure, but well at B should be successful. Water falling on the east side of the hill passes down planes of schistosity and enters the well at B. The well at A has only a small area from which to obtain water while the well at B obtains water from a considerable area.

moves down the planes of schistosity; well B has a larger collecting area because water is available from the schistosity planes intersected by the well, and the supply is augmented by water moving down the joint planes. In some localities, particularly where the relief is considerable, numerous failures are reported because the wells have been drilled on the wrong side of the hills. Difficulties of this type are most commonly encountered along Susquehanna River and its tributaries.

ARTESIAN CONDITIONS

The term artesian well is used in different ways. Some people in southeastern Pennsylvania call any drilled well an artesian well, others insist that only flowing wells should be classed as artesian; the first usage is incorrect, the second is too restricted. The term comes from the province of Artois, in France, where a flowing well was drilled in 1126.[1] Any well in which the water rises above the water table, or local ground-water level, may properly be regarded as an artesian well.[2] If the water is under sufficient pressure to rise above the surface the well may be called a flowing artesian well. To obtain a flowing well the water in the water-bearing bed must be under sufficient pressure so that when the bed is tappd by the drill the water will be forced upward through the well to the surface. The pressure is caused by the water being confined in a permeable bed that is overlain by beds of less permeable materials. The water-bearing bed must extend to a higher altitude in one or more directions and must be saturated up to a higher level than the land surface at the point where the well is situated. This difference in elevation produces the pressure. Under exceptionally favorable conditions the pressure is sufficient not only to cause overflow at the surface but to lift the water several hundred feet above the surface. In the artesian well at Woonsocket, South Dakota, the original pressure (1890) was reported to be 250 pounds to the square inch, or sufficient to lift the water about 575 feet above the surface.[3] A basin having artesian conditions is shown in Figure 4. Here the permeable bed lies between two impermeable beds and outcrops at elevations above the valley where flowing wells can be obtained. The rain or stream water that reaches the outcrop enters the permeable bed and is retained in it because the impermeable beds prevent its escape.

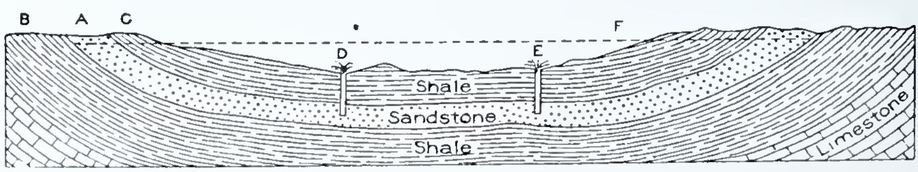


Figure 4. Diagrammatic section of an artesian basin produced by a syncline. A, Permeable stratum; B, C, impermeable strata below and above A, acting as confining beds; D, E, flowing wells supplied by the permeable water-filled bed A. The broken line (f) shows the approximate height to which the water will rise by artesian pressure except as the head is reduced by friction. (After Chamberlin.)

---

[1] Norton, W. H., Artesian wells of Iowa: Iowa Geol. Survey, vol. 6, pp. 122-126, 1897.
[2] Meinzer, O. E., Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, pp. 38, 39, 66, 67, 1923.
[3] Meinzer, O. E., U. S. Geol. Survey Water-Supply Paper 520, 1925. Pl. VI.

There are no large artesian basins in southeastern Pennsylvania, and the flowing wells that have been obtained in this area are due to relatively local structural features. In some places uniform dips, such as those shown in Figure 5, produce flowing wells. The uniform dips of the Triassic formations are favorable for flowing wells, except that they are in most places so thoroughly jointed that water seeps through the joint spaces and the pressure is thereby lost.

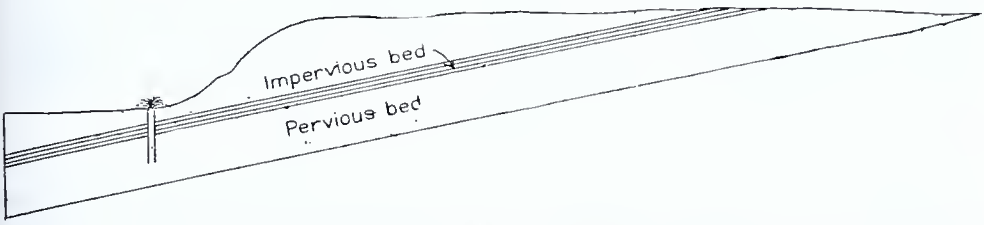


Figure 5. Ideal cross section showing artesian conditions produced by formations with monoclinal structure.

In certain localities underlain by gabbro a few flowing wells with small discharge are known. The explanation of these is apparently as follows: The uplands are frequently gravelly, and water falling on them percolates into the crevices in the gabbro. The hillsides and valleys are covered with nearly impermeable clay, and hence the water is retained in the openings in rock under pressure. (See Figure 6).

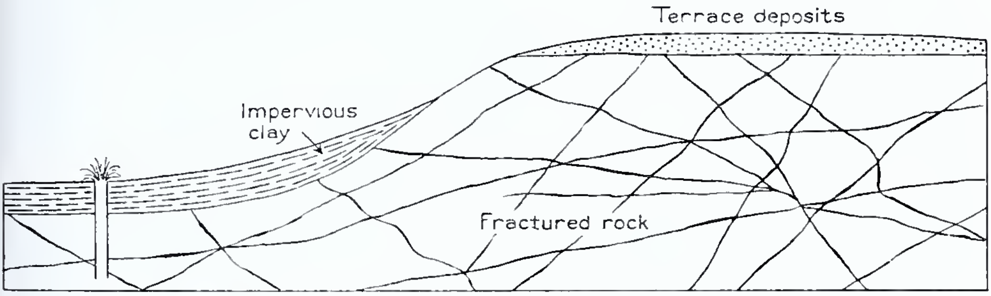


Figure 6. Ideal cross section showing artesian conditions produced by surficial clay overlying fractured rock.

In most places these conditions are not fulfilled and therefore flowing wells are rare even in the gabbro areas.

A few flowing wells are reported in the limestone areas. These penetrate solution channels that contain water under sufficient head to make them overflow. Unless the channel is closed at or near the lower end there is not likely to be sufficient head to produce a flowing well.

In many places the configuration of the surface and its relation to the contact between the fresh and disintegrated rock have an important bearing on the movement of the ground water. Many dug and drilled wells obtain water at such contacts, and a few of these wells receive water under sufficient pressure so that they overflow with slight head. The cause of the artesian conditions is shown in Figure 7.

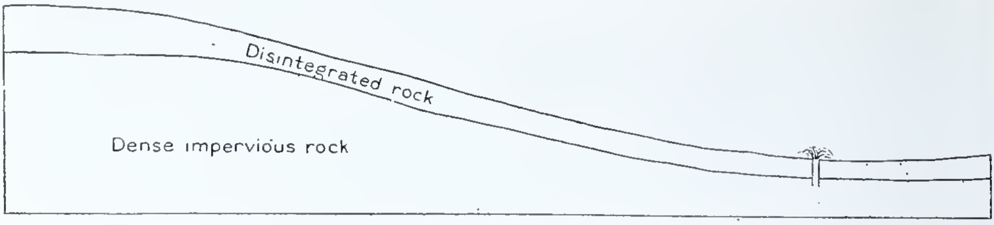


Figure 7. Ideal cross section showing artesian conditions produced near the bottom of the mantle of disintegrated rock overlying dense unweathered rock. The lower part of the mantle is relatively pervious but the upper part, which is more thoroughly weathered, forms an imperfect confining bed of relatively impervious clayey material.

Flowing wells are not abundant in southeastern Pennsylvania because in most places the conditions are not favorable. In many places, however, there is sufficient pressure to raise the water many feet above the level at which it enters the wells. Flowing wells are a great asset, and should be so regarded in the localities where they can be obtained. They should not be allowed to flow when the water is not used, because if the water is wasted the pressure will be reduced and the well from which water is wasted or some other flowing wells at higher levels may eventually cease to flow.

ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PROTEROZOIC ROCKS

PRE-CAMBRIAN METAMORPHIC ROCKS

WATER-BEARING PROPERTIES

This description is based on records of 337 wells, of which 220 end in the Wissahickon formation, 66 in the Baltimore gneiss, 27 in pre-Cambrian gneiss which was not correlated, 15 in the Peters Creek schist, 8 in schist of the Harpers phyllite, 3 in phyllite of the Harpers phyllite, and 2 in schist whose position in the stratigraphic column was not determined. The Harpers phyllite, although of Lower Cambrian age, is here included because of its similarity to the pre-Cambrian schists.

Schist, gneiss, and phyllite are rocks that have resulted from the metamorphism of igneous and sedimentary rocks. The gneiss is an impervious rock similar in its water-bearing properties to igneous rock. The schist and phyllite are likewise rather impermeable, although the planes of schistosity provide more or less space for the storage and movement of water. In some localities these rocks are jointed and faulted and along these fracture planes considerable water is stored below the water table. The following table summarizes the depths and reported yields of the 329 wells on which information was obtained.

Summary of reported yields of wells in gneiss, schist, and phyllite in southeastern Pennsylvania.

	Number of wells with specified limits of depth, in feet					
	100 feet or less	101 to 200 feet	201 to 300 feet	301 to 500 feet	More than 500 feet	Total
Total number of wells on which information was obtained	168	86	35	32	16	337
Dry holes or wells with very small yield	2	3	1	0	3	9
5 gallons a minute or less	45	21	7	5	2	80
5+ to 20 gallons a minute	95	41	10	9	3	158
20+ to 100 gallons a minute	26	21	14	16	6	83
100+ to 200 gallons a minute	0	0	3	2	2	7
More than 200 gallons a minute	0	0	0	0	0	0

The above table shows that almost one-half of the 337 wells were reported to yield between 5 and 20 gallons a minute. About one-fourth of all wells had reported yield between 20 and 100 gallons a minute. More than half of all the wells are 100 feet or less in depth. Most of these wells probably derive their water from the zone of weathered rock.

DESCRIPTION OF FORMATIONS

BALTIMORE GNEISS

General description. Baltimore gneiss, the oldest rock exposed in southeastern Pennsylvania, is found at the surface in Bucks, Montgomery, Philadelphia, Delaware, Chester, and Lancaster counties, and forms a discontinuous belt of varying widths on both sides of the Chester Valley. In addition to this elongated belt there are a number of isolated areas of this ancient gneiss. These patches, in general, have their longest dimension approximately parallel to the axis of the Chester Valley, but the area in the southeastern part of the State, which extends over into Delaware and Maryland, is very irregular in shape.

The Baltimore gneiss is a medium-grained crystalline aggregate of quartz, feldspar, hornblende, and mica. It is of sedimentary origin and is intruded by gneisses of igneous origin, which are in part of the same age and in part younger. It has two dominant facies, one graphitic and the other nongraphitic. In Chester County chiefly the graphitic gneiss becomes abundant. In Delaware County the gneiss is thoroughly injected with gabbro. These rocks are all mapped separately on the quadrangle maps prepared for folio publication but are not shown separately on the geologic map included in this report as Plate 1, except in the Reading Hills, Honeybrook uplands and the Martic overthrust block where graphitic and other sedimentary gneisses are shown by a separate pattern.

The igneous intrusives, which are not a part of the Baltimore, are much restricted areally and consequently much less important as a source of water supply than the sedimentary Baltimore gneiss. The intrusives can be seen north of Coatesville, near Phoenixville, and along Schuylkill River. They vary from light-colored, almost pure

quartz-feldspar rock to a dark gray rock in which garnets may be present in profusion together with hornblende, biotite, and rarely augite. The feldspars are orthoclase, albite, and oligoclase.

The Baltimore gneiss is characterized by conspicuous bands due to the alternation of layers of quartz and feldspar with layers of biotite. The biotite occurs in minute shining plates, but these flakes are not large enough to produce a schistose rock. Associated with the biotite are hornblende, epidote, titanite, garnet, and more rarely staurolite or augite. In some places hornblende becomes more abundant than biotite, and occasionally almost completely replaces the biotite. The hornblende, like the biotite, forms dark bands and the individual crystals have their elongation in the plane of the band in which it occurs. The feldspar is orthoclase and acid plagioclase approximating oligoclase, together with considerable microcline. The gneiss frequently has a pseudo-porphyritic texture due to lenses of quartz and feldspar scattered irregularly through the bands. These pseudo-phenocrysts are without crystal boundaries and suggest the possibility that they are metamorphosed pebbles. The biotite layers bend around the pseudo-phenocrysts. Rounded grains of resistant minerals, such as apatite, quartz, occur in the gneiss. These rounded resistant grains indicate the sedimentary origin of the rock.

The Baltimore gneiss is generally concealed beneath a thick mantle of soil except along streams where erosion is most active. The best exposures are in railroad and highway cuts and in quarries. This gneiss has been used for foundation stone, curbing, and flagging in the past, and a number of abandoned quarries afford exposures of different degrees of perfection. When fresh the gneiss is a very solid rock with few if any openings of larger than microscopic size. But weathering processes, long continued, are most destructive and the rock breaks down into soft material in which the original texture is retained but which is so soft that it can be excavated with a pick and shovel. The feldspars disintegrate, the quartz remains unchanged except that in places it apparently breaks into smaller fragments, the mica changes into chlorite, and the iron in accessory minerals is altered to limonite. The rock is thoroughly jointed, and frequently has four sets of joints.

A graphitic schist facies of the Baltimore gneiss, which in some reports has been called "Pickering gneiss," occurs in small areas in Chester, Delaware, Bucks, Berks, Northampton, and Lehigh counties. These areas are too small to show on map except in Reading Hills. The total area of outcrop is small, and although the rock was formerly a source of graphite,[1] it is not an important source of ground water. The rock is composed chiefly of feldspars, both plagioclase and orthoclase, quartz, biotite, hornblende, calcite, and much graphite. The less common constituents are pyrite, pyrrhotite, and magnetite, and their alteration products. The mineralogical composition and the texture vary greatly. In some places the rock is composed primarily of quartz and feldspar, in other places it is practically a quartz schist, in other places it contains both biotite and graphite, in others one of these constituents to the exclusion of the other; elsewhere the rock is so rich in calcite as to constitute a gradation toward the associated

[1] Miller, B. L., Graphite deposits of Pennsylvania: Pennsylvania Top. and Geol. Survey Comm., Report 6, pp. 74-82, 1912.

Franklin limestone.[1] Generally the rock occurs in layers which are rarely more than an inch thick, and in most places are so distinct that they give the rock a banded appearance.

The iron-bearing minerals break down under exposure to weathering processes and the soil derived from this rock is almost invariably stained red. Consequently the soil is of value in recognizing the underlying rock where the exposures are lacking.

Water supply. The Baltimore gneiss does not yield large volumes of water because where fresh the rock is dense and without pore space to store water. However, the joints or cracks by which the rock is broken hold some water, and although the percentage of joint space is small compared to the total volume of rock, they furnish storage for considerable quantities of water. Largely on account of these joints, wells sunk into this rock are usually successful where only small or moderate amounts of water are required. Although the vertical sets of joints, together with the horizontal set, form a considerable reservoir for water, periods of prolonged drought may cause very serious reduction in supply. Fault planes also form spaces for the storage of water, but although they are probably numerous in this rock, they are not sufficiently numerous to be of prime importance as a source of water. During the weathering of the gneiss joint planes are widened and other openings develop in the rock, and more or less water works its way along the bands in the gneiss. As a result of these openings due to weathering, a considerable volume of water is usually contained in the zone of partly altered rock lying between the fresh rock and the completely disintegrated rock. From this zone many wells draw their supplies.

The 64 wells in the Baltimore gneiss on which information was obtained range in depth from 30 to 380 feet and have an average depth of 86 feet. They range in reported yield from less than one gallon to 100 gallons a minute and average about 15 gallons a minute. The following tables give summaries of the wells in this formation:

Summary of reported yields of wells in the Baltimore gneiss in southeastern Pennsylvania.

Specified limits of depth, in feet	Number of wells	Range in yield, in gallons a minute	Average yield, in gallons a minute
100 or less	47	0–100	15
101 to 200	16	2½–30	11
201 to 300	2	8–10	9
301 to 500	1	----------	32

Summary of wells with specified limits of yield in the Baltimore gneiss in southeastern Pennsylvania.

	Dry holes or wells with very small yield	5 gallons a minute or less	5+ to 20 gallons a minute	20+ to 100 gallons a minute
Number of wells	1	2	34	9
Average depth in feet	50	105	86	123

[1] Franklin limestone is not shown on map but is mapped with the graphitic and other sedimentary gneisses.

Dry holes are not common, and probably average less than one in ten. If one drills 300 feet without encountering water, there is generally nothing gained by drilling deeper as the openings in the rock decrease in number and size with depth. It is far more advisable to abandon a hole that is still dry at the depth of 300 feet and to select a new site for drilling.

In selecting a site for a well hilltops and cliffs adjacent to deep valleys should if possible be avoided because drainage may have removed most of the water. The best sites are in broad open valley heads where the subsurface drainage converges; also on extensive plains and level or undulating uplands where the rock is weathered to considerable depth.

Due to the rather impervious character of the fresh gneiss lying beneath the partly disintegrated zone, most of the ground water is derived from precipitation which falls on lands at no very great distance. A part of the precipitation that soaks into the ground percolates through the soil into the partly disintegrated zone and travels laterally to points of discharge, where it forms springs. Where an upland is cut by a deep valley a spring zone may occur along the valley side where the contact between the underlying firm rock and the overlying weathered rock is exposed.

Because of the local source of the ground water care must be exercised in locating wells in relation to cesspools and barnyards. In rocks of this kind the ground water generally moves in about the same direction as the surface drainage but there may be exceptions to this rule. In any locality the water table will be depressed by pumping from a well and pollution that reaches the ground water will be drawn from some distance toward a well that is in use.

Seven samples of water from the Baltimore gneiss were analyzed. (See table at end of volume). Five of them range from 19 to 150 parts per million of total solids and from 9 to 58 per million of hardness. Two samples had over 300 parts per million of dissolved solids with hardness of 168 and 224 parts.

FRANKLIN LIMESTONE[1]

General description. In several places in Berks, Lehigh and Northampton counties a coarsely crystalline marble occurs which has been correlated on lithologic grounds with the Franklin limestone of New Jersey. Hand specimens from the Pennsylvania and New Jersey areas are indistinguishable, and stratigraphic relations indicate this correlation is probably correct. It occurs in parts of southeastern Pennsylvana as small lenses in the Baltimore gneiss.

The Franklin limestone is a coarse crystalline limestone, or marble, the individual particles of calcite being, in some places, as much as an inch in diameter. Graphite in small bright flakes approximately ⅛ inch in diameter is scattered through the marble and in most places the graphite is accompanied by flakes of the brown mica known as phlogopite. In some areas numerous silicate minerals are associated with the calcite.

No bedding planes are visible in the Franklin limestone outcropping in Pennsylvania, and therefore strike, dip, and thickness are un-

[1] Mapped with "graphitic and other sedimentary gneisses" in Reading Hills, Honeybrook Upland and Mine Ridge Upland and with the Baltimore gneiss in other areas.

determinable. However, it is probable that the maximum thickness does not exceed a few hundred feet.

Water supply. This limestone or marble is not an important source of water, but some wells draw their supplies from it. The rock is very dense and contains little water except in joint planes and solution channels. For a description of the water-bearing properties of limestones, see p. 41.

No samples of water were collected from the Franklin limestone. This limestone is in many places nearly pure calcite with only subordinate amounts of magnesium-bearing minerals. The water derived from the Franklin limestone will therefore probably be hard but the hardness is likely to be mainly bicarbonate hardness which is largely removed by boiling.

SETTERS FORMATION

General description. The Setters formation is well developed in Chester County, where it frequently forms ridges beside the valleys underlain by Cockeysville marble. Its topographic expression is due largely to hardness and chemical stability.

The formation is composed of quartzite, mica gneiss, and mica schist. The quartzite is a cream white to grayish tan, fine grained, thin bedded crystalline rock. The white mica, sericite, is developed paralled to the bedding planes and causes the rock to split easily into flat slabs. The mica gneiss is a fine grained, slightly banded gneiss containing quartz, biotite, and muscovite with a small quantity of feldspar, chiefly microcline. With an increase in the mica content the rock becomes a pinkish to grayish green mica schist with a beautiful frosted sheen. This schist is sometimes confused with the schists of the Wissahickon formation but can usually be distinguished by its relative position with the overlying marble and its straight instead of crinkled bedding planes. The occurrence of "stretched" black tourmaline on the bedding planes is a striking feature of this formation. By stretched tourmalines are meant those broken and linearly displaced crystals which are so conspicuous at many localities.

Water supply. In some places the Setters formation forms hills which are often woodland and along the foot of the hills small springs are common. In other places it forms rolling uplands which are cultivated and rather thickly inhabited. A number of wells have been drilled in the formation and most of these have yielded small quantities of very good water. The quartzite and the other rocks composing this formation are distinctly dense rocks through which little water could percolate but they are jointed, and their bedding planes, which are more or less open, form a considerable reservoir for water. However, wells yielding large volumes of water will be exceptional and failures will occur where the rocks are without joints or open bedding planes. The water obtained from this formation, particularly from the quartzites, probably would be low in total dissolved solids and free from objectionable constituents. Nine wells drilled in Setters formation, in regard to which information was obtained, range in depth from 30 to 170 feet and average 87 feet. Their reported yield ranges from 2 to 25 gallons a minute and averages 14 gallons a minute.

COCKEYSVILLE MARBLE

General description. Marble is exposed in three areas in lower Chester County, which may be designated for convenience as the Doe Run, Avondale, and Landenberg areas, and in one small area in York County. It is considered to be equivalent to the Cockeysville marble[1], which is of Algonkian age. The pure, fresh rock consists of a medium-grained, highly crystalline, lustrous, white, granular marble characterized by the abundant development of accessory minerals, of which phlogopite, the magnesia mica, is the most abundant of the accessory minerals and in places is so plentiful that on planes parallel to the bedding the rocks appear to be composed entirely of brown mica. In other places tiny plates of phlogopite are so evenly and thickly scattered through the marble that it simulates granite and is locally known as "bastard granite." Biotite, muscovite, tourmaline in large black and brown crystals, magnetite, apatite, and pyrite are common accessory minerals. In places, the accessory minerals appear to make up the bulk of the rock, but careful inspection reveals that calcite or dolomite is the dominant mineral and the accessory minerals are more conspicuous because of color or form.

In general the marble weathers to a deep clay soil and natural outcrops are uncommon. Deep railroad and highway cuts expose the marble but the best exposures were formerly in the numerous quarries which were opened for one purpose or another. Many of these quarries are now abandoned and filled with water, and afford small and frequently rather inaccessible exposures.

Water supply. Among the many reasons reported for the abandonment of the quarries not the least important is trouble with water. While very few of the quarries were probably abandoned solely on account of difficulties in coping with water, it evidently caused considerable difficulty. The quarry at Avondale yields so much water that it is now used as a source of supply for the town, which consumes approximately 50,000 gallons a day.

Although most abandoned quarries are filled with water, the total quantity of water flowing into any one of them probably did not exceed 500 gallons a minute and when the total surface exposed in the quarries is considered the inflow per unit of surface, or the percolation factor, is very small. The inflow is reported to have occurred in a few places chiefly along enlarged joint planes, and the greater part of the rock was dry.

Drilled wells in the marble are usually successful at depths not exceeding 250 feet but failure to obtain water occurs in about one in every twenty wells. Marble is a dense, impervious rock through which little or no water can percolate, but in most places it is jointed and some of the joints have been enlarged by solution, forming openings of considerable size. The regional history has been one of successive uplift separated by periods of base-levelling. There have apparently been no periods of depression in which solution channels developed at or near the level of the water table could have been depressed to considerable depth below the water table.

Nineteen wells ending in the Cockeysville marble in regard to which information was obtained range from 34 to 280 feet in depth and

[1] Bascom, F. and Stose, G. W., U. S. Geol. Survey Geol. Atlas, Coatesville-West Chester folio (No. 223), 1932.

average 150 feet. They range in reported yield from less than 1 gallon to 110 gallons a minute and average about 31 gallons a minute. For further description of the water-bearing properties of this formation see the summary of water-bearing properties of limestones on p. 41. The water from this formation is moderately hard, like the other limestone water in the area. Analyses of three samples obtained from this formation showed total solids ranging from 109 to 271 parts per million and hardness ranging from 62 to 249 parts per million. The three samples analyzed were virtually free from iron. (See Chester County analyses at the end of the report).

WISSAHICKON FORMATION

General description. The Wissahickon formation is widely distributed in southeastern Pennsylvania. This formation, which varies considerably in its lithology, ranging from gneiss to schist, was named from its exposure along Wissahickon Creek, a tributary of Schuylkill River, in Fairmount Park, Philadelphia. The formation is beautifully exposed along the East Drive, which follows first the river and then the creek, so that many residents of southeastern Pennsylvania are familiar with this formation. The large flakes of glistening white mica attract the attention and arouse the curiosity of many who pass along this picturesque drive. Unfortunately, the gneiss here has been so thoroughly injected by pegmatite that the rock exposed is hardly typical of the formation, but it gives an impression of its micaceous character.

Although the Wissahickon formation is a stratigraphic unit, it is a heterogeneous one. In the southern part of the State, particularly in Chester and Lancaster counties, it consists of schist rather than gneiss, and has two distinct facies,—the oligoclase mica and the albite-chlorite. These facies are described in the report on the McCalls Ferry-Quarryville District, by Knopf and Jonas[1].

With the exception of the variations which will be described below, this formation may be described as a medium to coarse grained, banded rock, characterized by a large amount of mica, and ranging from a gneiss to a schist. The constituents of the rock are quartz, feldspar, orthoclase, and plagioclase, green or brown biotite, muscovite, and chlorite, and in some areas, garnets, which may occur in great profusion. Magnetite, apatite, zircon, tourmaline, garnet, andalusite, sillimanite, and zoisite are accessory constituents. The more gneissic beds contain abundant orthoclase and plagioclase, approximately oligoclase and andesine. While considerable feldspar is often present, mica, chiefly muscovite, is usually the more abundant and conspicuous mineral.

The belt of gneiss passing through Chestnut Hill and Bryn Mawr, formerly called the Chestnut Hill belt, is composed of beds which are alternatingly micaceous and quartzose. On weathering, these beds, owing to their highly developed cleavage, split readily into pencil-like fragments likened to "half rotted fibrous wood." The yellow color resulting from the oxidation of the ferruginous minerals, together with the brownish black stains on the joints, make a striking resemblance to fragments of rotten wood. The formation is very garnetiferous where intruded by peridotitic rocks.

[1] Knopf, E. B. and Jonas, A. I., Geology of the McCalls Ferry-Quarryville District, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 25-35, 1929.

The oligoclase-mica schist is a finely plicated, medium-grained rock composed of biotite, muscovite, and quartz, with a variable amount of feldspar as well as chlorite. Garnet is usually present. The albite-chlorite facies of this formation is an albite schist interbedded with chlorite or muscovite schist. It is spotted with white crystals of albite that show most prominently on rough surfaces at right angles to the schistosity of the rock. Other minerals present are quartz, calcite, garnet, magnetite, and tourmaline. Pyrite and other sulphides of iron are present and weather to hydrated oxides of iron which stain the rock yellow.

The schistose varieties of the Wissahickon formation are sparkling gray to green schists which weather to a brownish red clay soil filled with glittering flakes of mica and containing buff to red slivers of schist. The two facies of the schist have the same chemical composition, and it is now known that they were derived by metamorphism of arkosic sediments, that is, sediments that consisted largely of fragments of unweathered feldspar. They differ in mineral content, however, because of the difference in degree of metamorphism which each has undergone. Oligoclase-mica schist found in the extreme southeastern part of the area was metamorphosed in a deeper zone under greater heat and pressure than the albite-chlorite schist which is found farther northwest. A view of a good exposure of the Wissahickon formation is shown on Plate 3, A.

Water supply. The Wissahickon formation is a fairly good source of water supply. Wells drilled into it can usually be depended upon to obtain sufficient water for domestic use. Unweathered rocks of this formation are dense and lack porosity which is so essential for the circulation of water, but fortunately thorough jointing provides openings for the storage and circulation of the water. Although these openings are numerous and hold considerable amounts of water, their total volume is small when compared to the pore space in a porous rock such as unconsolidated sand or gravel. In addition to jointing, the Wissahickon formation has been faulted in many areas so that fault planes afford additional storage for water. Although fault planes are numerous, it is not unusual for wells to miss them completely and consequently they are of less importance as a source of water than the joint planes, which furnish most of the supplies to drilled wells.

Joint planes decrease in number and in size of opening with depth, and consequently they contain less water at considerable depths than near the surface. For this reason if a well is dry at 300 feet it is not advisable to continue drilling deeper because the chances of obtaining an adequate supply decrease with depth. In the schist, the planes of schistosity may contain some water but in fresh rock these openings are mainly of subcapillary size, and although they may contain water they do not yield it freely. The zone of altered or partly altered rock, near the surface, contains more openings than the fresh rock and is potentially a source of larger volumes of water. The joints are more numerous and in general the planes of schistosity have been opened wider, and both sets of openings may contain considerable water. Many of the older dug wells obtain their supplies from the weathered zone and do not penetrate solid rock to any great depth. Many drilled wells also obtain a considerable part of their supplies

from this zone. Wells should be situated to take advantage of the dip of the schistosity and the direction of the flow of the ground water. (See fig. 3, p. 15).

The average depth of 220 wells in the Wissahickon formation is 187 feet. They range from 35 to 1,825 feet in depth. The reported yields range from less than 1 gallon to 170 gallons a minute and average about 23 gallons a minute. The following tables give summaries of the wells in this formation. The average depth of the five wells with very small yield is probably too high to be representative of all the dry holes in this formation because two wells, 1,825 and 1,000 feet deep, are included in this average.

Summary of reported yields of wells in the Wissahickon formation in southeastern Pennsylvania

Specified limits of depth, in feet	Number of wells	Range in yield, in gallons a minute	Average yield in gallons a minute
100 or less	101	0–100	14
101 to 200	55	0–100	19
201 to 300	26	2–170	50
301 to 500	25	3–150	55
More than 500	12	0–150	47

Summary of wells with specified limits of yield in the Wissahickon formation in southeastern Pennsylvania

	Dry holes or wells with very small yield	5 gallons a minute or less	5 to 20 gallons a minute	20 to 100 gallons a minute	100 to 170 gallons a minute
Number of wells	5	48	98	62	7
Average depth in feet	630	126	147	250	400

The Wissahickon formation usually yields water low in total dissolved solids and free from objectionable minerals except iron. The 13 waters from this formation that were analyzed range in total dissolved solids from 40 to 126 parts per million and in hardness from 16 to 69 parts. (See tables pp. 242-249). Four of these waters contain more than 4 parts per million of dissolved iron, which makes them undesirable for many uses. Most of the waters analyzed, however, contain less than one-half of 1 part and the great majority of well owners do not complain of undesirable quantities of iron. In some localities underlain by this formation the water is undesirably hard. This hard water is due to the occurrence of numerous pegmatite dikes, many of which contain large percentages of lime-soda feldspar. At Chatham, where hard water was obtained from this formation, the well is reported to be in feldspar. In many places the dikes are so thoroughly concealed that their presence is revealed only by the drill and it is therefore difficult to avoid the hard water.

PETERS CREEK SCHIST

General description. The Peters Creek schist takes its name from Peters Creek, a small stream which drains part of Lancaster County and flows into Susquehanna River at Peach Bottom Station. This schist outcrops in a synclinal band of varying width that extends northeastward from the Maryland State line, crosses the Susquehanna and disappears before reaching the Schuylkill River. Except where cut off by faulting, it is bounded on both sides of the syncline by the Wissahickon formation.

The Peters Creek schist[1] is a chloritic, sericitic quartzite interbedded with chlorite-muscovite schist. There are a few thin sandstones near the top of the formation. The fresh rock is gray to greenish, but the iron-bearing parts weather easily and the iron may stain the rock yellow. The soils resulting from weathering are difficult to separate from those of the Wissahickon formation. The rock contains feldspar, quartz, muscovite, sericite, chlorite, and accessory minerals, such as pyrite and magnetite, are frequently very abundant. The feldspar, which is chiefly albite, is very much less abundant than in the gneisses and schists of the underlying Wissahickon formation. The metamorphism of the Peters Creek schist is much less than that of the Wissahickon formation, and in places the fresh rock upon close examination betrays its sedimentary origin. However, metamorphism has been sufficiently great to alter the sodium-bearing minerals to albite. At the exposure along Susquehanna River near the mouth of Peters Creek, the schist is tightly folded and exact measurements of thickness are difficult. The combined thickness of this formation and the Wissahickon formation is probably between 4,000 and 5,000 feet.

Water supply. The Peters Creek schist has about the same water-bearing properties as the Wissahickon formation. Most wells will yield small supplies at depths of less than 150 feet, and many wells encounter supplies adequate for domestic use at much shallower depths. Wells which can be considered failures will not be more than one in twenty. The rock where fresh and unaltered is relatively dense, and a rather poor water horizon. However the rock is rather thoroughly jointed and the planes of schistosity are somewhat open in all but the freshest rock and these openings afford space for the storage and circulation of considerable water. Fifteen wells in this formation in regard to which information was obtained range in depth from 35 to 160 feet and average 91 feet. They range in yield from 1 to 70 gallons a minute and average about 13 gallons a minute.

The water from the Peters Creek schist is somewhat similar to the water from the Wissahickon formation. In most places it is relatively low in total dissolved solids but in some places the dissolved mineral matter is higher and the water is rather hard. Some well owners report hard water, others report the presence of considerable iron. Analyses of four samples of water from this formation suggest that the water may be as a rule somewhat harder than that from the Wissahickon formation. Thus three of the Peters Creek schist waters have respectively 113, 136, and 186 parts per million of hardness whereas the hardest of the 13 Wissahickon waters had only 69 parts. One of the samples from the Peters Creek schist is, however, a soft water as it showed only 18 parts of hardness. Three of the samples are also rather high in dissolved iron.

[1] Knopf, E. B., and Jonas, A. I., loc. cit., pp. 35-37.

CARDIFF CONGLOMERATE[1]

General description. The Cardiff conglomerate directly overlies the Peters Creek schist. It occurs in a belt of variable width about 15 miles long which extends southwestward from Fairmount in Lancaster County, Pennsylvania, across York County to Pylesville, in Harford County, Maryland. The formation was named from the town of Cardiff, Maryland, immediately adjoining Delta, Pennsylvania, on the Maryland-Pennsylvania State line. In the lower beds of the conglomerate there is an alternation of schistose and conglomeratic layers which marks the transition from Peters Creek schist to the Cardiff sediments. The Cardiff conglomerate is marked by a predominance of quartz in the pebbles. Most of the pebbles are completely granulated and many are deformed and elongated. The matrix of the conglomerate is schistose and is composed of fine quartz, fibers of sericite and chlorite. The Cardiff conglomerate and the Peach Bottom slate are mapped together on Plate 1. The exact age of these sediments is not known.

Water supply. This formation is of limited areal extent and is not an important water-bearing formation. It is dense and impervious and ground water occurs in the joint, schistosity, and fracture planes. Wells in this conglomerate should obtain small supplies at depths which do not exceed 300 feet. Conglomerates are frequently excellent aquifers but the matrix of this one is too dense.

PEACH BOTTOM SLATE[1]

The Cardiff conglomerate grades upward through beds of alternating conglomerate and slate into roofing slates which form an area about 6 miles long and half a mile wide. This slate was named from the prominent exposure along Susquehanna River near Peach Bottom Station in Lancaster County. The Peach Bottom slate is dark bluish gray, non-fading, and of a strong luster on cleavage surfaces. It consists of muscovite, quartz, andalusite, and graphite, with variable amounts of magnetite and pyrite. Excellent exposures of this slate can be seen in the quarries on both sides of the Maryland-Pennsylvania State line at Delta, in York County. The total thickness of the formation is probably about 1000 feet. It is mapped with the Cardiff conglomerate on Plate 1.

Water supply. This slate is not an important aquifer in York and Lancaster counties where it is exposed. Slate is impervious and the available ground water occurs in bedding, joint, cleavage, and fracture planes. Few wells have been drilled in this formation. The quarries are large and some water enters them but the volume is small compared to the size of the quarry openings. The slate is a rather unfavorable water-bearing formation.

PRE-CAMBRIAN IGNEOUS ROCKS

WATER-BEARING PROPERTIES

The following description of yield of water in the pre-Cambrian igneous rocks is based on 137 wells, of which 94 end in gabbro, 21 in serpentine, 3 in granite, 2 in pegmatite, and 5 in igneous rock which

[1] Knopf, E. B. and Jonas, A. I. loc. cit., p. 36–39.

is not subdivided into rock types. In addition, 12 wells end in Triassic diabase.

Fresh, unweathered igneous rock is very dense, with little or no space for the storage and movement of water. Where a surface of moderate or slight relief is underlain by igneous rock, there is commonly a zone of weathered rock material, usually less than 100 feet thick, which is permeable and from which considerable supplies of water can be obtained. In this region these rocks have been fractured and if one of the fracture planes is encountered in a well at a depth below the water table, good yields will be obtained. Joints and other like openings decrease in size and number with increasing depth, so that deep drilling is commonly unsuccessful. The following table summarizes the depths and reported yields of wells in igneous rocks.

Summary of reported yields of wells in igneous rocks in southeastern Pennsylvania

	Number of wells with specified limits of depth in feet					
	100 feet or less	101 to 200 feet	201 to 300 feet	301 to 500 feet	More than 500 feet	Total
Total number of wells on which information was obtained	107	20	5	2	1	135
Dry holes or wells with very small yield	2	2	0	0	0	4
5 gallons a minute or less	57	7	0	0	0	64
5 to 20 gallons a minute	35	8	1	0	0	44
20 to 100 gallons a minute	11	3	1	2	1	18
100 to 200 gallons a minute	2	0	3	0	0	5
More than 200 gallons a minute	0	0	0	0	0	0

This table shows that more than four-fifths of the wells in igneous rocks upon which information was obtained are less than 100 feet deep. Most of these wells probably derive their water from the zone of weathered rock. It is common practice to drill to the contact of the weathered and unweathered rock. More than four-fifths of the 135 wells have reported yields between 5 and 100 gallons a minute. The 135 wells range from 16 to 1 000 feet in depth and average about 84 feet. They range in reported yield from less than 1 gallon to 120 gallons a minute and average about 13 gallons a minute.

DESCRIPTION OF TYPES

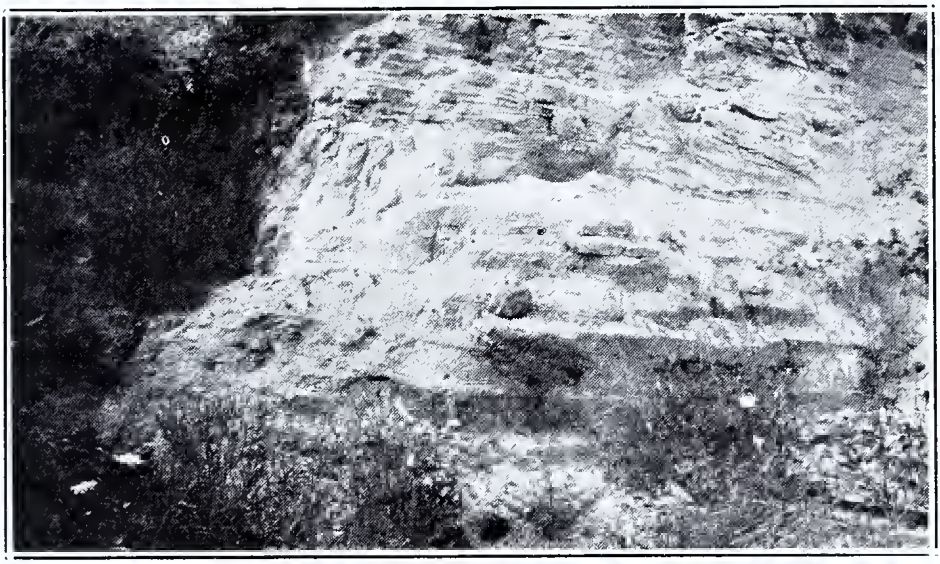
GRANITE AND ALLIED ROCKS

General description. Under this heading are included granite, granite gneiss, grano-diorite, quartz-diorite, and anorthosite. Intrusive rock of granitic character is well exposed in Philadelphia, Montgomery, Delaware, Lehigh, Bucks, Lancaster, Northampton, Berks, and Lebanon counties. The exposure in Philadelphia County is limited to a small area on the banks of Schuylkill River, at the Falls of the Schuylkill. West of the river the outcrop expands southwestward toward Delaware River. Near the Delaware the formation is, however, covered

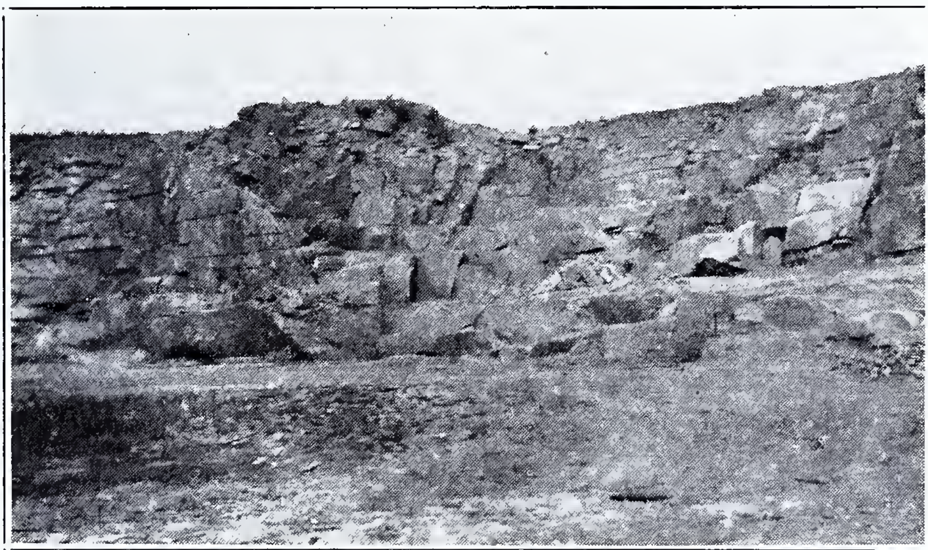
with a mantle of coastal plain deposits. There are also a number of isolated areas of this rock.

The rock of the main mass is medium to coarse grained, typically gneissoid in some parts and characteristically porphyritic. The large

PLATE 2.



A. Weathered granite near Lima, Delaware County.



B. Granite in quarry near Lima, Delaware County.

crystals, or phenocrysts, are light, flesh-colored orthoclase and range from half an inch to 1¼ inches in length. The chief constituents of the rock are quartz, feldspar, biotite, and hornblende. Muscovite may be present but is not as characteristic a constituent as is biotite. The feldspar is chiefly orthoclase and microcline and subordinately oligoclase.

The intrusive granite is gneissoid in the vicinity of Philadelphia but to the south and west the gneissoid character is less conspicuous. In places, particularly in the centers of large intrusive masses, the gneissoid phase gives way to a massive one. The gneissic-banding is due to metamorphism of the intrusive masses, and is a conspicuous feature where developed.

This granitic rock is derived from a magma that was intruded into the Baltimore gneiss and the Wissahickon formation, and, consequently, it is younger than these formations. It has in turn been intruded by gabbro and other ultrabasic rocks now altered to serpentine. The relations of these rocks to one another are well shown in the Pennsylvania Railroad cut between Glen Riddle and Lenni Mills. As the granitic rock intrudes pre-Cambrian formations but does not anywhere in this area invade Cambrian or younger rock, its age is quite certainly pre-Cambrian. Two views of the granite are shown on Plate 2.

Associated with the granite are quartz-diorite, grano-diorite, quartz-monzonite and anorthosite. The quartz-monzonite and the anorthosite are, in places, separately mapped, but in other areas they are included with the granite. (See Plate 1.) The quartz diorite[1] which is a light gray rock of granitic texture with poorly defined banding is not separately mapped. It consisted originally of oligoclase, andesine, quartz, and mica, with subordinate amounts of accessory minerals. It has been altered and zoisite has developed. Grano-diorite is also not separately mapped. It is a medium coarse-grained, dark gray rock composed of quartz, feldspar, and ferromagnesian minerals, which is intermediate between the granites and the diorite.

Water supply. The water-bearing properties of the granitic rocks resemble those of the Baltimore gneiss, and in most places these rocks will yield small supplies to drilled wells although somewhat less favorable as a source of water than the Baltimore gneiss. The rocks are jointed and faulted and water occurs chiefly in the joint and fault openings. Failures in drilling wells will not occur more frequently on the average than in one well out of every twenty drilled. If, however, a well is dry at a depth of 250 feet it is good practice to select a new site and drill another well because the water-bearing openings decrease in number with depth. The water-bearing properties of quartz-diorite, grano-diorite, quartz-monzonite and anorthosite are similar to those of granite.

The water from the granitic rock probably would in general be low in total dissolved solids and low in hardness. However, where the calcium content of the rock is large, water may be higher in total dissolved solids and somewhat harder.

ANORTHOSITE

General description. Anorthosite is a medium to coarse grained rock composed exclusively or chiefly of labradorite or a closely related variety of feldspar. It occurs in several counties in southeastern Pennsylvania and an area near Honeybrook, in Chester County has been described by Isabel F. Smith[2]. The rock can usually be distinguished

[1] Knopf, E. B. and Jonas, A. I., loc. cit, p. 64.
[2] Smith, Isabel F., Genesis of anorthosites of Piedmont Pennsylvania: Pan Am. Geologist, vol. XXXVIII, pp. 29 to 51, 1922.

from surrounding rocks by its grayish-blue color and spheroidal weathering. The color is due to the development of the secondary mineral zoisite which almost entirely replaces the feldspar. Fields underlain by anorthosite are strewn with large, well rounded light grayish-blue, smooth surfaced boulders. In hand specimens the fresh rock is medium to coarse-grained, pinkish-gray in color and is composed almost entirely of clear feldspar crystals which show bright cleavage surfaces. The feldspars are four or five millimeters in diameter on the average but a few exceptional ones are over two centimeters in length. Ferromagnesian minerals occur in sparing amounts.

Water supply. The water-bearing properties of anorthosite resemble those of granite.

QUARTZ-MONZONITE

General description. Quartz-monzonite is a medium to fine grained, dark gray rock composed of quartz, feldspar, pyroxene, amphibole, and biotite. In places the rock shows a foliated texture. It outcrops in several counties in this area, and an occurrence in Chester County has been described by Miss Smith[1]. The feldspars are orthoclase and plagioclase and are present in nearly equal amounts. Ferromagnesian minerals are very abundant. The quartz-monzonite weathers to dark, oxidized, rough and pitted surfaces and the rock crumbles readily due to removal of less resistant ferromagnesian minerals.

Water supply. The water-bearing properties of quartz-monzonite resemble those of granite.

GABBRO AND ALLIED ROCKS, INCLUDING HORNBLENDE-GNEISS AND SCHIST

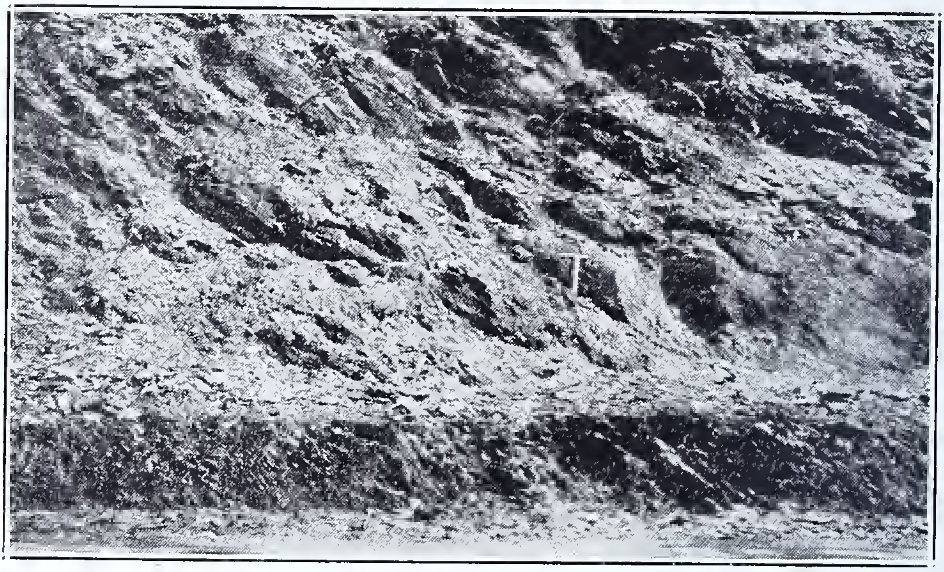
General description. Gabbro, including meta-gabbro, hypersthene gabbro, norite and hornblende-gneiss and schist, intrudes the older rocks in large and small masses along the southeastern edge of the Piedmont Province in Pennsylvania. It is exposed in disconnected areas of different size and shape. Gabbro is an important rock in southeastern Pennsylvania and extends in a belt from Delaware River to Maryland and Delaware State lines with its maximum development of outcrop in Delaware County. In most places the gabbro is easily recognized by the rust-colored boulders or "nigger heads" as they are locally called, lying in the fields. In the vicinity of Booth Corner residual boulders are so numerous as to interfere with cultivation of some fields and the great size of the boulders immediately attracts attention. Natural exposures of solid rock are rare. In many places the gabbro has intruded the Baltimore gneiss, and due to the presence of the rust-colored boulders of gabbro the gneiss is masked and is only revealed in deep cuts and quarries.

The gabbro is, in general, a medium-grained, massive rock with a bronzy to greenish-gray color, the shade depending on the freshness of ferro-magnesian constituents of the rock. When encountered in a well, the wet cuttings frequently have a blue appearance and the name "blue rock" is used by drillers for gabbro. In hand specimens quartz, feldspar, and pyroxene may be determined but under the microscope the gabbro is a typical hypersthene-augite-plagioclase rock with ac-

[1] Smith, Isabel F., loc. cit. p. 43–44.

cessory quartz, biotite, hornblende, magnetite, apatite, titanite, pyrite, pyrrhotite, garnet, and orthoclase. In weathered specimens the presence of actinolite, chlorite, and serpentine is easily detected. Quartz is an extremely variable constituent; it may be absent or may range up to

PLATE 3.



A. Wissahickon formation south of Coatesville, Chester County.

B. Boiling Springs, Cumberland County.

30 per cent. The pyroxene may be exclusively hypersthene, when the rock is called norite, or, less frequently, chiefly augite and the rest hypersthene, when it is called hypersthene gabbro, or exclusively augite or diallage, when the rock is a typical gabbro. The pyroxene makes up from 10 to 40 per cent of the rock. The feldspar is labradorite or bytownite and composes 5 to 60 per cent of the rock. While these varieties of gabbro are important to the student of rocks, they resemble

each other so closely when studied in hand specimens or in quarries that it is almost impossible to distinguish them from one another. Their water-bearing properties are virtually the same.

The age of the gabbro has been discussed by many authors and it is the concensus of opinion that it is pre-Cambrian. The youngest rock that it intrudes is the Wissahickon formation, which is of Algonkian age.

Penetrating the Baltimore gneiss and the Wissahickon formation are numerous basic dikes which have been largely altered to hornblende gneiss. Many of these dikes are connected directly with the larger intrusive masses of gabbro, but in other cases such connections are concealed. These dikes are common in the southern parts of Chester and Delaware counties. They vary in width up to 100 feet and locally to half a mile. In the vicinity of Philadelphia these dikes are common but usually very narrow. In the broader dikes the rock is massive, but in the narrower ones it is schistose. The prevailing mineral is hornblende but there is also some feldspar and a little quartz, some of which is probably secondary. The accessory constituents are apatite, titanite, magnetite, pyrite, and abundant garnets. These dikes weather rather easily and a number of secondary minerals develop. The hornblende, which gives the rock its dark green to greenish-black color, is an alteration product from augite. Its origin is shown by the occurrence of unaltered augite with rims of green hornblende.

Water supply. Gabbro and related rocks rarely yield large supplies of water. Indeed, gabbro is possibly the most unfavorable rock for production of water supplies among the crystalline rocks of the area. It is very massive and almost impervious, and is, consequently, not a good source of water. In many places the main supply obtained by wells in this rock is from the junction of weathered and fresh rock. In certain places where the gabbro is jointed, there are wells that yield more than 100 gallons a minute.

The hornblende gneiss is similar to gabbro as a source of water except that the planes of schistosity where opened by weathering afford a somewhat better reservoir for water and consequently yield somewhat larger supplies. In most places this rock outcrops in long narrow strips, the total area of which is inconsiderable, and consequently it is not so important as a source of water as is the gabbro, which outcrops over large areas.

The average depth of 94 wells in gabbro is 91 feet, ranging from 25 to 1,000 feet. The reported yields of these wells range from less than 1 gallon to 120 gallons a minute and average about 14 gallons a minute. The following tables summarize the wells ending in gabbro.

Summary of average reported yields of wells in gabbro, in southeastern Pennsylvania

Specified limits of depth, in feet	Number of wells	Range in yield, in gallons a minute	Average yield in gallons a minute
100 or less	72	0–125	12
101 to 200	13	0–100	22
201 to 300	6	8–175	45
301 to 500	2	2–130	66
More than 500	1	-----	60

Summary of wells with specified limits of yield in gabbro, in southeastern Pennsylvania

	Dry holes or wells with very small yield	5 gallons a minute or less	5 to 20 gallons a minute	20 to 100 gallons a minute	More than 100 gallons a minute
Number of wells	3	45	26	14	3
Average depth in feet	86	65	87	176	200

The water obtained from the gabbro is usually low in total dissolved solids. The four samples that were analyzed range from 69 to 140 parts per million in total solids and 40 to 65 parts in hardness. They are all low in their content of iron, the range being from .05 to .21 parts per million. The rust-stained boulders so conspicuous on areas underlain by the gabbro as well as the red color of the soil suggest, however, that considerable amounts of iron might be found in waters from this rock.

SERPENTINE AND ASSOCIATED ROCK

General description. More or less closely associated with the gabbro are pyroxenite and peridotite that have been altered to serpentine. In Pennsylvania areas of serpentine occur from Delaware River to the Maryland State line, and the masses increase in area of outcrop toward the south and southwest from Bucks County, through Philadelphia and Delaware counties, into Chester and Lancaster counties. The largest areas are those along the Maryland State line.

Although serpentine is one of the most easily recognized rocks it shows great variation in color and appearance. In color it ranges from buff or white to a deep emerald green or from light yellowish green to dark blue-green with which are associated shades of reddish brown. The light colors usually accompany an earthy texture and dark colors a compact stony one. In general the rock has a greenish hue and, frequently, an oily appearance. The reader should bear in mind that the rock serpentine is composed essentially of a mineral of the same name which is a hydrous silicate of magnesium, but may contain in addition to the mineral serpentine, which occurs in a number of varieties, many other minerals. These minerals have made the serpentine "barrens" a favorite hunting ground for mineralogists. Among the minerals found in these areas are talc, asbestos, anthophyllite, tremolite, hornblende, actinolite, epidote, chlorite, clinochlore, vermiculite, pectolite, magnetite, hematite, limonite, calcite, breunnerite, magnesite, quartz (chiefly drusy quartz), chalcedony, opal, chromite, and corundum.

The serpentine areas along the Maryland State line were the source of the world's supply of chromite for several decades prior to the Civil War, but the opening of richer deposits in other parts of the world relegated these to the position of reserves. During the World War mining was revived in a Maryland mine on the State line, but the termination of hostilities brought this activity to a close. In places the serpentine is cut by dikes of feldspar, chiefly albite, which has been extensively mined by the open cut method. The numerous abandoned open cuts, some of which are flooded, add interest to an exploration of the "barrens."

As one approaches the serpentine areas he is aware of their proximity on account of the use of serpentine for building material. Quarries can be opened in the serpentine with little difficulty, and, owing to its softness, it can be easily worked. The rock is usually well jointed, facilitating quarrying operation. However, joints as well as irregular fractures are frequently so numerous that it is impossible to get out pieces of desirable size or shape for ordinary building purposes. Some of the serpentine shows a tendency to fade, which makes it less desirable for building purposes. The areas mapped as serpentine in Plate 1 are not underlain by serpentine exclusively, nor by rocks in which serpentine is the chief constituent. In some areas the serpentine has been completely removed by solution and disintegration for several feet below the surface and only siliceous ironstone remains; but in other areas the serpentine crops out with less than an inch or two of soil. In some places the pyroxenite and peridotite have been altered not to serpentine but to talc, anthophyllite, or chlorite, producing soapstone, anthophyllite rock, or chlorite schist, which are very different in appearance from serpentine.

Even small serpentine areas have a marked and characteristic appearance because most of the areas underlain by this rock stand out as ridges. The rock is soft, indeed so soft that one can cut it away with an ordinary pocket knife, but chemically it is very inert when exposed to ordinary weathering and hence it makes low hills and ridges. In many places the ridges and hills are residual remnants which are left in relief due to the erosion of the surrounding areas of more easily decomposed rocks. On the uplands the soil is light green, more or less closely resembling the underlying rock; but in the valleys it is red, due to oxidation of the iron. The soil resulting from the decomposition of serpentine is notorious for sterility. The cause of this sterility is an unsettled problem; one group arguing that the essential plant foods are lacking, another, that the soil is thin and lacks the power to retain moisture, and another that the excessive amount of magnesium present in the soil is detrimental to plant growth. Whatever may be the cause, plants with few exceptions do not thrive on this soil, and the flora is distinctly poor in number of species and individuals when compared with that of the surrounding country. The moss pink (*Phlox subulata*) covers the ground in sufficient profusion to give the areas a pink tinge when the flower is in bloom, from which the name of "Pink Hills" is derived. Scrub pines, cedars, oaks, and cat briar are all characteristic of the serpentine areas. In the southern part of the State, these areas are so wild and barren and scrub pines are so numerous that they are called "Pine Barrens," or "The Barrens."

Water supply. Serpentine is a dense rock but in most areas joints and fractures are numerous and extend to such depths that the rock holds considerable volumes of water. However, the serpentine areas are in most instances somewhat elevated above the surrounding country, and frequently partly dissected by valleys which facilitate the loss of water stored in the openings. Consequently, small springs are not uncommon at the contact of the serpentine and the surrounding rocks, as well as in valleys cut in the serpentine. In former years considerable dependence was placed in these springs. Shallow dug wells located in the valleys also yielded adequate supplies. But both springs

and shallow dug wells show great difference in yield according to the season, and in extremely dry periods many of them run dry. In recent years a number of drilled wells in the serpentine have proved successful. Wells usually obtain their supply within the first 150 feet. With increasing depth the joints and other fractures tend to close up and the quantity of available water to become less. Wells should be cased for the first few feet, but except in deeply weathered serpentine the holes at greater depths will stand unsupported for years.

The average depth of 21 wells ending in serpentine is 98 feet. They range from 40 to 323 feet. Their reported yields range from less than one gallon to 70 gallons a minute and average about 10 gallons a minute. One well 103 feet deep was reported as dry.

Analyses of 6 samples of water from the serpentine range from 87 to 333 parts per million in total dissolved solids and 43 to 317 parts per million in hardness. The hardness in three samples is due almost wholly to the presence of magnesium. In each of the other three the hardness due to magnesium is from one-half to one-third of the total hardness. Most natural waters contain much more calcium than magnesium but waters from serpentine are likely to contain more magnesium than calcium. In the sample analyzed having the largest proportion of magnesium, the magnesium content was 76 parts and the calcium content only 2.1 parts. Usually the magnesium content is not too high for ordinary domestic use, but it is reported that at the Westtown Boarding School the magnesium content was so high that the supply was abandoned and new wells were sunk in limestone. The content of iron is also rather large in some of the waters analyzed.

APORHYOLITE AND METABASALT (GREENSTONE)

General description. The pre-Cambrian rocks of South Mountain consist almost entirely of volcanic materials, chiefly lavas, but some pyroclastic material. The lavas, which include rhyolite, quartz-porphyry, and basalt, have all been highly altered but not sufficiently to completely obliterate their volcanic origin. These rocks were long thought to be sedimentary, but the work of Williams[1] and Bascom[2] definitely established their igneous origin. These rocks have been recently described by Stose[3]. These volcanic rocks are also exposed in the Pigeon and Hellam Hills to the east, and metabasalt or greenstone also occurs associated with Cockeysville marble near the Maryland State line. The pre-Cambrian schists and gneisses and the associated deep-seated intrusions so conspicuous in the pre-Cambrian rocks exposed between the Susquehanna and Delaware rivers are not exposed in South Mountain, Pigeon Hills, or Hellam Hills.

The volcanic rocks have been divided into acid and basic groups to which the names aporhyolite and metabasalt have been given by Miss Bascom[4]. The term aporhyolite includes relatively fresh rhyolite, devitrified rhyolite, and rhyolite tuff which has been altered to sericite schist. The texture of the aporhyolite is variable but it is usually fine-grained and compact with development of amygdules in places.

[1] Williams, G. H., The volcanic rocks of South Mountain in Pennsylvania and Maryland: Amer. Jour. Sci., 3d. ser., vol. 44, pp. 482–496, 1892.
[2] Bascom, Florence, The ancient volcanic rocks of South Mountain, Pa.: U. S. Geol. Survey Bull. 136, 1896.
[3] Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), pp. 4–5, 1929.
[4] Bascom, F., op. cit. pp. 20–21.

Phenocrysts, though frequently numerous, are rarely prominent, but flow lines and spherulites are conspicuous in places. The rhyolite is a compact rock ranging in color from deep red to purple and blue with conspicuous feldspar phenocrysts. The sericite schist has a well developed slaty cleavage which resembles bedding planes. The cleavage was partly responsible for the earlier workers considering the rocks to be sedimentary. Sericite frequently imparts a silvery appearance to the cleavage planes.

The metabasalt, or greenstone as it is commonly called in the region, is apparently in part younger than the aporhyolite but in part they overlap and interfinger[1]. In its least altered state the greenstone is a dark, compact rock speckled with dark green chlorite, light yellowish green epidote, or white quartz. Usually it is a compact greenstone or a dark chlorite schist, and much of it is amygdaloidal. The vesicles are filled with quartz, calcite, epidote, and chlorite, and give the rock a spotted appearance. Some amygdaloid is flattened to a spotted slate. In places it is intensely crushed and sheared, and veined with chlorite, quartz, and epidote, and a little asbestos. Locally the greenstone is called copper rock on account of native copper occurring in it and also because of its green color.

Water supply. Both of these volcanic rocks outcrop in rough mountainous country that is sparsely inhabited, and hence only a few wells have been drilled in them. Springs that yield small but excellent supplies are numerous and, supplemented by dug wells in the valleys, they furnish sufficient water for rather sparse population. Parts of the South Mountain area in Franklin County are used for summer resorts and a number of wells have been dug and drilled. Blue Ridge Summit, Buena Vista Springs, and Charmian use well water from the greenstone, as do many private residences. Some of the abandoned workings of the copper mine at Charmian are filled with water, and considerable difficulty with water in these workings was reported. However, if the area of the opening is considered in relation to the total amount of water pumped the inflow from each unit of area was only a small fraction of a gallon a minute. Apparently water supplies adequate for domestic purposes can be obtained by drilling wells 250 or 300 feet deep, but some failures may occur. Yields exceeding 25 gallons a minute are not common. Although the rocks are much jointed and broken, openings decrease in size below 300 feet and the probabilities of obtaining supplies become increasingly unfavorable. The aporhyolite, on account of its shattered condition, is probably a more prolific source of water than the metabasalt. In places the metabasalt yields large supplies, but in some areas it is too dense and too thoroughly metamorphosed to yield large quantities of water.

PALEOZOIC ROCKS

OUTLINE OF FORMATIONS

The Paleozoic formations make, in total thickness, an enormous mass of rocks. The oldest Cambrian sediments were gravel, sand, and mud which have been altered to form conglomerate, sandstone, quartzite, shale, and phyllite, depending on the original composition and the

[1] Stose, G. W., and Bascom, F., loc. cit., page 4.

amount of metamorphism. The remainder of the Cambrian sediments and the older Ordovician sediments are largely calcareous, forming the so-called "Valley limestones." The younger Ordovician sediments are a great thickness of shale, some beds of which, in the region between the Lehigh and Delaware rivers have been altered to slate.

The Cambrian and Ordovician rocks form a belt of variable width extending in a great arc from the Maryland State line across the southeastern part of the State to Delaware River. The belt is interrupted by prongs of the old crystalline rocks and by troughs in which occur the predominantly red sandstone and shale of Triassic age.

The sedimentary beds show different characteristics at different localities, and demonstrate that geologic formations are not of the same thickness and kind of sediment at points many miles apart. As a result of these variations, different formational names are used in different parts of the State. Consequently, it will be necessary to present several sections representative of different areas and some formations more or less equivalent in time relations, which may not differ much in lithology, although thicknesses are generally very different, will be described. Of course, where their lithology is similar their water-bearing characteristics will be about the same.

WATER-BEARING PROPERTIES OF THE QUARTZITES

Of 46 wells recorded which end in quartzite, 27 are in the Hardyston quartzite, 12 are in the Chickies quartzite, and 7 are in the Setters formation. Although the latter is of pre-Cambrian age, it is included in this summary of the Paleozoic quartzites because of its similar lithologic character.

A true quartzite is a sandstone in which the pore space between the sand grains has been more or less completely filled with silica. This produces a hard, dense, impermeable rock in which there is little space for the storage and movement of water. There are all gradations between a dense, almost impervious quartzite and a friable, permeable sandstone. In this region the quartzites have been fractured and jointed and were it not for these openings and the fact that, in places, the rocks are more nearly sandstones than quartzites, much smaller supplies would be obtainable from them. The following table gives a summary of the depths and reported yields of wells ending in quartzite:

Summary of reported yields of wells in the Chickies, Hardyston, and Setters quartzites in southeastern Pennsylvania

	Number of wells with specified limits of depth, in feet					
	100 feet or less	101 to 200 feet	201 to 300 feet	301 to 500 feet	More than 500 feet	Total
Total number of wells on which information was obtained	21	9	8	3	5	46
Dry holes or wells with very small yields	0	0	0	1	1	2
5 gallons a minute or less	5	2	1	0	1	9
5+ to 20 gallons a minute	13	3	3	0	1	20
20+ to 100 gallons a minute	2	3	3	2	2	12
100+ to 200 gallons a minute	1	1	0	0	0	2
More than 200 gallons a minute	0	0	1	0	0	1

Almost one-half of the wells yield between 5 and 20 gallons a minute. More than half of them are less than 200 feet deep. The 46 wells range in depth from 30 to 1069 feet and average about 210 feet. The reported yields of these wells range from less than 1 gallon to 225 gallons a minute and average about 34 gallons a minute. The average yield would probably be considerably less if some of the wells were not in sandstone.

Six samples of water from the Cambrian quartzites and related sandstones were analyzed. These waters are all low in dissolved mineral matter, ranging from 17 to 64 parts per million and averaging 30 parts. They are all soft waters, ranging in hardness from 7.8 to 27 parts per million and averaging 14 parts. Their content of iron ranges from 0.3 to .78 parts per million and averages .26 parts. The waters from the springs or wells in these formations are very desirable for domestic and industrial uses and should, so far as practicable, be recovered and carried in pipe-lines to the settlements in adjacent limestone areas.

WATER-BEARING PROPERTIES OF THE LIMESTONE, DOLOMITE AND MARBLE

This description is based on the records of 345 wells which are distributed in the several formations as follows: 64 in the Conestoga limestone, 96 in the Conococheague limestone, 30 in the Elbrook limestone, 51 in the Beekmantown limestone, 19 in the Cockeysville marble, 14 in the Ledger dolomite, 18 in the Tomstown dolomite, 22 in undifferentiated Cambrian and Ordovician limestones, 5 in the Vintage dolomite, 24 in the Stones River limestone, 2 in the Chambersburg limestone, and 3 in the Jacksonburg limestone. All but those in Cockeysville marble are in rocks of Paleozoic age, but because of similar lithologic characteristics, the wells in the Cockeysville marble (Algonkian) are here included in this summary.

Limestone, dolomite, and marble are dense impervious rocks. They are, however, quite soluble and where water has moved along fracture planes, openings have been produced. The occurrence of these solution channels is very irregular. Many cases are on record where, for example, one well 100 feet deep encountered a channel and yielded 100 gallons a minute, while a 500 foot well near by penetrated only solid limestone and yielded very little or no water.

Wells deriving their water from solution channels are liable to serious contamination because of the rapidity with which the water moves along the channels. Care should therefore be taken in choosing a site for a well that is near sources of pollution.

The following table gives a summary of depths and reported yields of wells in these rocks.

Summary of reported yields of wells in limestone, dolomite, and marble in southeastern Pennsylvania

	Number of wells with specified limits of depth, in feet					
	100 feet or less	101 to 200 feet	201 to 300 feet	301 to 500 feet	More than 500 feet	Total
Total number of wells on which information was obtained	121	110	60	30	24	345
Dry holes or wells with very small yield	4	4	4	4	6	22
5 gallons a minute or less	38	15	6	2	5	66
5+ to 20 gallons a minute	42	53	12	3	2	112
20+ to 100 gallons a minute	31	30	24	12	4	101
100+ to 200 gallons a minute	3	6	8	6	3	26
More than 200 gallons a minute	3	2	6	3	4	18

The above table shows that about one-fourth of the 345 wells yielded 5 gallons a minute or less, whereas about one-eighth of them yielded more than 100 gallons a minute. More than two-thirds of these wells are less than 200 feet deep.

Analyses were made of a total of 41 waters obtained from limestone, dolomite, and marble, chiefly from the calcareous formations of the Cambrian and Ordovician systems. Nearly all of these waters are fairly high in total dissolved solids, their mineral contents consisting largely of the bicarbonate of calcium and magnesium, which give them considerable hardness. The 41 samples ranged in total solids from 75 to 889 parts per million but nearly three-fourths of them were between 200 and 500 parts and their average content of dissolved solids was 304 parts. The same samples ranged in hardness from 24 to 508 parts per million, nearly two-thirds of them having between 100 and 250 parts and nearly one-third having more than 250 parts of hardness. They showed an average hardness of 239 parts per million. The limestone waters are generally low in iron, only 2 of the 41 samples having more than 1 part per million and over half of them having less than one-tenth of 1 part per million of this undesirable constituent. Except for their hardness the limestone waters are as a rule excellent waters.

DESCRIPTION OF FORMATIONS

CAMBRIAN SYSTEM. LOWER CAMBRIAN SERIES

LOUDOUN FORMATION

General description. The Loudoun formation is the oldest Cambrian formation exposed in this area. It outcrops in South Mountain in York, Adams, Cumberland, and Franklin counties. It is a variable formation which was made from the products of disintegration of the older crystalline rocks. It was named from exposures in Loudoun County, Virginia, and displays great variability in its type locality, where it ranges from slate through shale, sandstone, and conglomerate. In the South Mountain area, where it is about 800 feet thick, it is less variable and calcareous phases are absent. The formation is not

separately mapped but is included with the Weverton sandstone in Plate 1.

Water supply. The formation consists chiefly of sandy shale which has been metamorphosed almost to a schist, and is so dense that it will yield little water except from such openings as joint planes. Most of the localities where the Loudoun formation is exposed are so sparsely settled that springs take care of the needs of most of the inhabitants. However, drilled wells would probably obtain small supplies of soft water from this formation.

WEVERTON SANDSTONE

General description. The Weverton sandstone, named from a prominent outcrop on the Potomac near Weverton, Maryland, is probably the most conspicuous formation in the South Mountain area. It consists entirely of siliceous fragments, mainly quartz and feldspar. Its texture varies from very fine, pure sandstone to moderately coarse conglomerate, but the conglomerate phase is subordinate. The sandstone is usually thoroughly cemented but not sufficiently dense except locally to be called a quartzite. The thickness of this formation is approximately 1,250 feet. On the map, Plate I, the Loudoun formation is included with the Weverton sandstone.

Water supply. The Weverton sandstone outcrops are chiefly in rough, wooded mountain country where occasional springs are adequate to supply the needs of the inhabitants. Hence very few wells have been drilled in this sandstone, and data concerning even these are not available. It would probably yield considerable water, though much of it is too thoroughly cemented to permit easy circulation of water except through joints. In general, fairly ample supplies should be obtained at depths of less than 500 feet, and the water should be low in total dissolved solids and free from objectionable constituents except that in some localities iron may be present in sufficient quantities to prove annoying. The two samples of water that were analyzed from the Weverton sandstone (See analyses—Adams and Cumberland counties) are the least mineralized and among the softest waters that were collected in the area, the solids being respectively only 17 and 19 parts per million. They are also virtually free of iron. Due to the folding and faulting in the region surrounding South Mountain, the Weverton sandstone is too deeply buried to be available as a source of water supply except in small areas.

CHICKIES AND HARDYSTON QUARTZITES

General description. The Chickies quartzite, which takes its name from Chickies Rock on Susquehanna River, is a thick-bedded, light-colored, vitreous quartzite, in which the quartz grains are clear white or blue. The upper part of the formation is thin-bedded and in places disintegrates into a fine white siliceous clay. The basal part of the formation is composed of the Hellam conglomerate member, which consists essentially of granular quartzite and pebbly conglomerate with blue quartz grains and pink feldspar fragments. This conglomerate member takes its name from the Hellam Hills in York County, where it has a thickness of about 500 feet and contains coarse beds

PLATE 4.

A. Massive beds of Chickies quartzite in quarry 1 mile east of Kinderhook, Lancaster County. Photo by Jonas and Stose.

B. Siliceous banded limestone of the Conococheague near Vogansville, Lancaster County.

of conglomerate. The massive beds in this formation are shown on Plate 4, A.

The Chickies formation is about 400 feet thick, and on account of its resistant nature it caps hills, among the more prominent of which are Pigeon Hills, Hellam Hills, Chickies Ridge, Barren Hill, and Welsh Mountain. In the Reading-Durham Hills and in South Mountain south of Allentown the Cambrian quartzite is generally called the Hardyston quartzite. It resembles the Chickies quartzite with a similar conglomerate at the base, but no Harpers formation overlies it. It is mapped with a separate pattern on Plate 1.

Water supply. Both the Chickies quartzite and the Hardyston quartzite outcrop in areas that are generally sparsely inhabited and in which there are few wells about which reliable information can be obtained. Drilled wells should generally produce small supplies at depths not exceeding 250 feet. On account of the dense character of the rock most of the water will be obtained from joint and bedding planes, and because of the elevated position of most outcrops, the water table may be far below the surface. The average depth of 39 wells ending in the Chickies and Hardyston quartzites is 241 feet. These wells range in depth from 40 to 1,069 feet, range from less than 1 to 225 gallons a minute and average 39 gallons a minute. The 7 deepest wells, with an average depth of 713 feet, have an average reported yield of 35 gallons a minute.

The water is generally exceptionally low in total dissolved solids and is very soft. The two samples from Chester and Lancaster counties that were analyzed from the quartzite of the Chickies formation have respectively only 19 and 27 parts per million of hardness and the sample analyzed from the Hellam conglomerate member at Honeybrook, Chester County, has a hardness of only 9.3 parts. The water from these beds, together with that from the other Cambrian quartzites and sandstones, is therefore the most desirable ground water in the area for domestic and industrial uses.

HARPERS PHYLLITE

General description. The Harpers phyllite which is about 1,200 feet thick and overlies the Weverton sandstone and the Chickies quartzite, was named from Harpers Ferry, West Virginia, where it is beautifully exposed. The formation is composed chiefly of shale which is a dark bluish-gray when fresh and weathers to a light dirty greenish-gray. This formation outcrops in a belt to the west of the Weverton sandstone and usually marks a rolling depression below the uplands formed by the hard underlying sandstone. A series of high hills formed by the Montalto quartzite member runs parallel to the scarp of South Mountain in Franklin and Adams counties.

The Montalto quartzite member ranges from a thickness of approximately 20 feet at the Maryland-Pennsylvania line to 750 feet in the vicinity of Montalto Mountain, the type locality, to about 1,000 feet a few miles north of Montalto. It thickens rapidly and is probably 1,500 feet thick at the maximum. This quartzite is usually light-colored, and frequently more or less iron-strained. Fossil worm-borings, *Scolithus linearis,* are very common in some beds. The Montalto member is separately mapped on Plate 1. The overlying Antietam

sandstone is combined with the Harpers on the map because of its narrow outcrop.

The degree of metamorphism of the Harpers phyllite varies with the locality. The region about Welsh Mountain, Lancaster County, is one of the most thoroughly metamorphosed areas. Here it is altered to a schist locally while areas at no very great distance are much less metamorphosed. The phyllite is estimated to be 1,500 feet thick here and is a sericitic albite phyllite of gray color and characteristic oily luster. In Mine Ridge Hill it has been altered into albite-mica schist which is coarsely crystalline and distinctly foliated.

Water supply. Like all schistose formations, the Harpers phyllite yields relatively small quantities of water, but the Montalto quartzite member carries much water of great purity, similar to the Weverton sandstone. Where the rock is metamorphosed it is especially dense but has a larger number of water-bearing joints. This formation will generally yield small supplies of water for domestic use. The 11 wells in this formation in regard to which information was obtained range in depth from 65 to 368 feet and have an average depth of 218 feet. They range in reported yield from 1½ to 10 gallons a minute and have an average yield of only about 6 gallons a minute. The Montalto quartzite member yields large volumes of water to springs at its contact with underlying shale, but its capacity to yield water to wells has not been thoroughly tested.

The water from the Harpers phyllite is not as low in mineral matter or in hardness as that derived from the underlying Weverton sandstone or the Chickies quartzite. However, it is not nearly so hard as the limestone waters. The five samples from this formation that were analyzed range in total solids from 22 to 123 parts per million and average 71 parts. They range in hardness from 14 to 58 parts and average 37 parts. Two of the five waters are practically free of iron, one is high in iron, and two are of intermediate iron content.

ANTIETAM SANDSTONE

General description. The Antietam, which overlies the Harpers phyllite, is essentially a light-gray quartzitic sandstone with a calcareous cement. In the region east of Susquehanna River the phyllite grades upward into the Antietam. The Antietam is a biotite quartzitic sandstone with calcareous, vitreous quartzite beds at the top. The calcareous beds weather to a dark red, ferruginous soil containing fragments of porous, rusty, banded quartzite, and form an excellent horizon marker for the top of the arenaceous Lower Cambrian series. In this area the Antietam is about 150 feet thick. On the map it is combined with Harpers formation because of its narrow outcrop.

Water supply. Few wells have been drilled into the Antietam in the eastern area. It will doubtless yield small supplies but probably not large industrial supplies. The water is likely to be of good quality, as is indicated by the one sample from Montalto, Franklin County, which was shown by analysis to be very soft and low in iron and other mineral constituents.

TOMSTOWN DOLOMITE

General description. The Tomstown dolomite, the oldest calcareous formation of Cambrian age in the western part of the area covered by this report, takes its name from Tomstown, Franklin County. In the eastern part of the area the equivalent rocks are divided into Vintage and Ledger dolomite separated by the Kinzers formation. The Tomstown is composed largely of dolomite and limestone, both massive and thin-bedded, with considerable interbedded shale near the base. This formation, on account of its soluble character, usually forms depressions between the mountain and the low ridges formed by the overlying Waynesboro formation. In many places a large part of the land underlain by Tomstown dolomite is covered by wash from the mountains which conceals the lower beds of the formation and ruins the land for agricultural use. It is approximately 1,000 feet thick.

Water supply. Few wells from which trustworthy data are available have been drilled in this formation. The average depth of 18 wells ending in the Tomstown dolomite is 184 feet and they range from 80 to 400 feet. Their reported yields range from 3 to 100 gallons a minute. One sample of water from this formation in Cumberland County was analyzed. It is a typical limestone water with 240 parts per million of dissolved solids and 205 parts of hardness, practically all of which is bicarbonate, or temporary hardness. It contains .78 part per million of iron.

VINTAGE DOLOMITE

General description. The calcareous quartzite at the top of the Antietam grades upward through a white micaceous dolomite into the Vintage dolomite in the eastern part of the area. The Vintage dolomite outcrops chiefly in York, Lancaster, and Chester counties, where, in places, it occupies valleys between ridges of Antietam quartzite and the overlying Kinzers formation. At the base the Vintage dolomite is cream-white, impure dolomite containing white mica on the bedding planes. This impure dolomite is overlain by heavy-bedded gray dolomite and a knotty blue dolomite. The best exposures of this dolomite are in the cuts of the Pennsylvania Railroad west of Vintage. The thickness of this dolomite is approximately 600 feet in the vicinity of the type locality, but may be different in other localities. It is mapped with the Kinzers formation on Plate 1. The Vintage dolomite is shown on Plate 5, A.

Water supply. Like most dolomites the Vintage dolomite is dense, and, except where it is broken by faulting or jointing or traversed by solution channels, it will yield very little water. Five wells in the Vintage dolomite range in depth from 40 to 125 feet and average 85 feet. They range in reported yield from 10 to 60 gallons a minute, and average 33 gallons a minute. For further description of the water-bearing properties of limestone, dolomite, and marble, see page 41. No information is available concerning attempts to drill through the lower beds of the limestone into the underlying Antietam sandstone where somewhat softer water might be obtainable.

PLATE 5.

A. Upper part of Vintage dolomite overlain by Kinzers shale exposed in cut on Pennsylvania Railroad near Vintage, Lancaster County. Photo by Knopf and Jonas.

B. Thin-bedded limestone typical of Conestoga formation.

KINZERS FORMATION

General description. The Kinzers formation, which overlies the Vintage dolomite, was named from exposures in cuts on the Pennsylvania Railroad near the town of Kinzers in Lancaster County. In the type locality it consists of thin beds of impure dolomite at the base, overlain by hackly blue shale with dark-banded argillaceous dolomite and beds which are mixtures of nodular white marble and blue dolomite. In the vicinity of Lancaster it is chiefly blue shale. This formation is only 130 feet thick at the type locality, thins rapidly eastward and northward, and disappears in a relatively short distance. It forms low hills between outcrops of the Vintage and Ledger dolomites. It is combined with the Vintage dolomite on Plate 1.

Water supply. The Kinzers formation is probably a poor source of water though it may yield small domestic supplies. Frequently wells will pass through these beds and obtain their supplies from the underlying Vintage dolomite. There is so much calcareous material in this formation that waters from it will be very little different in mineral content from those in the underlying dolomite. They are all hard waters. Information on only two wells in this formation was obtained. One is 75 feet deep and yields 25 gallons a minute; the other is 99 feet deep and yields 7 gallons a minute.

LEDGER DOLOMITE

General description. The Ledger dolomite, which is about 1,000 feet thick, is well developed in York, Lancaster, Montgomery, and Chester counties. It takes its name from the village of Ledger, in Lancaster County. It is a granular, sparkling, gray to white dolomite generally thick-bedded, with massive, glistening, dark-blue to mottled dolomite at the top. It weathers to rough surfaces and yields a deep-red, granular, clay soil.

Water supply. The Ledger dolomite should yield small supplies of hard water, and where a well intersects large solution channels filled with water, large supplies may be obtained. Little information is available concerning deep wells in this dolomite, but if the experience gained in deep drilling in the limestones of adjacent regions can be used here, not much water will be found below the depth of 300 feet. The average depth of 14 wells in this formation is 145 feet. They range from 60 to 485 feet. They are reported to yield from less than 1 gallon to 110 gallons a minute and the average reported yield is about 22 gallons a minute.

WAYNESBORO FORMATION

General description. The Waynesboro formation, of Lower and Middle (?) Cambrian age, which overlies the Tomstown dolomite, was named for the borough of Waynesboro, Franklin County, northeast of which it is well exposed. The formation consists chiefly of calcareous sandstones, red and purple shales, and subordinate limestones, and on account of its resistant siliceous character it usually forms hills, ridges, and knobs parallel to the mountain front. At the base is a siliceous limestone which, on weathering, appears to be a porous sandstone. This sandstone and associated chert and secondary vein

quartz litter the ground in some localities. In the past boulders from this source were gathered and used for fencing. In the middle of the formation are dark blue limestone and fine-grained white marble which are not usually exposed. The top of the formation is composed of siliceous limestone, mottled slabby sandstone, and dark purple siliceous shale. The siliceous beds usually form ridges while the more calcareous beds in the middle frequently erode more rapidly and form a depression. The total thickness of these beds probably does not exceed 1,000 feet.

Water supply. While the siliceous beds look like porous sandstones where they outcrop, they are thoroughly cemented with calcareous material at some depth and are less favorable as water horizons than a surface inspection might lead one to believe. This formation yields small supplies in some places, but due to its siliceous character solution channels are not numerous, and large supplies, such as are occasionally encountered in limestones containing solution channels, are probably not obtainable from this formation. The thin sandstones near the top of the formation may yield somewhat larger supplies, but they are also rather thoroughly cemented at some depth.

MIDDLE AND UPPER CAMBRIAN SERIES

ELBROOK LIMESTONE

General description. In the western part of the area covered by this report the Elbrook limestone, of Middle and Upper Cambrian age, overlies the Waynesboro formation, while in the central and eastern part it rests upon the Ledger dolomite. It is not known to be present in the easternmost part of the area. On the map (Plate 1) the Elbrook and Conococheague limestones are combined. In the western part of the area the Elbrook limestone forms a series of beds of gray to light-blue shaly limestone and calcareous shale. The lower half of the formation is shaly, with included limestones that are minutely laminated and weather readily to calcareous shaly plates. Many of these shales are green with some thin red bands. At the base, however, some rather massive limestones are found. Near the middle of the formation there are locally massive beds of dolomite and siliceous limestone which weather to porous slabby sandstone. The upper half of the formation is composed of light-colored calcareous shale and thinly laminated limestones that weather shaly. In the western part of the area the formation has a maximum thickness of about 3,000 feet.

In the central part of the area the Elbrook limestone is not well exposed, but its thickness is about 500 feet or approximately one-sixth of its thickness in the western part of the area. The formation here consists of a thin cherty sandstone at the base, overlain by fine-grained, thin-bedded, dove-gray or blue, magnesian limestone with some argillaceous layers. It contains some beds of cream-colored marble with sericitic partings. The soil of the Elbrook limestone is usually distinctly lighter in color than the clays derived from the Ledger dolomite.

Water supply. The shaly beds are rather impervious and the sandy beds are too thoroughly cemented to permit ready circulation of water. Large supplies can probably not be developed but small domestic supplies should be obtained. The average depth of 32 wells in this forma-

tion is 116 feet. These wells range from 35 to 300 feet in depth. Their average reported yield was 13 gallons a minute and their range in yield from 2 to 60 gallons a minute. See also the summary of water-bearing properties of limestone, dolomite, and marble on page 41.

Two samples of water from this formation in Lancaster County were analyzed. They resemble the hard limestone waters, containing respectively 332 and 483 parts per million of total solids and having 296 and 373 parts per million of hardness. A spring issuing from the Elbrook in Franklin County carries 242 parts per million of dissolved solids.

UPPER CAMBRIAN SERIES

CONOCOCHEAGUE LIMESTONE (OZARKIAN OF ULRICH)

General description. The Conococheague limestone, which takes its name from the excellent exposure along Conococheague Creek, overlies the Elbrook limestone, with noticeable unconformity in places where the contact of these formations is well exposed. In Franklin and adjacent counties the base of the Conococheague limestone is recognized by the presence of conglomerates and siliceous beds which form low hills. The conglomerates are of two types—ordinary pebble, and edgewise. The normal pebble conglomerate consists of rounded pebbles of limestone up to 1 inch in diameter in a matrix of coarse sand; the edgewise conglomerate consists of long slender fragments of limestone tilted in all directions and inclosed in a calcareous matrix. The origin of the "edgewise" conglomerate is still undetermined although there has been considerable discussion of the problem.[1]

The body of the formation consists of closely-banded blue limestone. The bands range from minute laminae to layers half an inch or more in thickness which are invisible or inconspicuous in the fresh rock but are brought out by weathering as yellow sandy streaks across the light blue or gray background. In the more siliceous phases the sandy beds stand out in high relief. These siliceous bands are conspicuous on Plate 4, B.

In the central part of the area the Conococheague limestone consists of a series of impure, thick-bedded, glistening, dark-blue limestones and dolomites, black chert bands, and marbles. The dolomite beds weather rough and the argillaceous limestones to a mud rock in which the siliceous bands stand out prominently. Both have large masses of the fossil Cryptozoon which are large concentrically laminated masses in reef-like aggregations thought to be calcareous algae. In the eastern part of the area it has in some reports been called Allentown limestone. In the western part of the area the Conococheague has a measured thickness of 1,635 feet, but in Lancaster County it is estimated to be 1,000 feet thick. The Conococheague limestone is mapped with the Elbrook limestone on Plate 1.

Water supply. Statistics based on 36 wells in the Conococheague limestone show that it is one of the best, if not the best, water-yielding limestone in the region. These wells have an average depth of

[1] Bassler, R. S., Maryland Geol. Survey: Cambrian and Ordovician, pp. 86-88, 1919.
Stose, G. W., Mercersburg-Chambersburg Folio: U. S. Geol. Survey Geol. Atlas No. 170, p. 6. 1909.
Brown, T. C., Notes on the origin of certain Paleozoic sediments: Jour. Geol. vol. 21, pp. 233-244, 1913.
Grabau, A. W., Principles of stratigraphy: pp. 530, 784, New York, 1924.

228 feet and range from 36 to 1,012 feet in depth. Their average reported yield was 168 gallons a minute, and their range in yield from less than 1 gallon to 1,450 gallons a minute. Five of the 36 wells are 400 feet or more in depth, averaging 662 feet. These 5 wells also had the largest reported yields of wells in this formation, the average for the 5 wells being 890 gallons a minute. Two of the 36 wells were reported as being dry. They are 350 and 262 feet deep. For a description of the occurrence of water in limestone, dolomite, and marble, see page 41.

Four samples of water from the Conococheague limestone in Lancaster and Northampton counties were analyzed. They are all rather hard, ranging in total dissolved solids from 172 to 889 parts per million and in hardness from 149 to 508 parts per million. All four are low in dissolved iron.

ORDOVICIAN SYSTEM

BEEKMANTOWN LIMESTONE

General description. The Beekmantown limestone, named for a town in New York, is about 2,300 feet thick in Franklin County, 2,000 feet in Lancaster County, and thins to 1,000 feet in Northampton County, and lies between the Conococheague and the Stones River limestones. It consists of a series of layers of magnesian and nonmagnesian beds of varying thickness. Its diagnostic feature is the minutely laminated appearance on freshly weathered surfaces due to the differential weathering of the pure and impure bands. Near the base the bands are so sandy that it is difficult to separate this formation from the underlying Conococheague limestone.

Another striking feature of this limestone is the abundance in the lower part of the "edgewise" conglomerate, mentioned under the Conococheague limestone. It is possibly somewhat more common in the western than in the eastern part of the area. It contains beds of pink marble in the western and central part of the area but their presence is not reported in the eastern part. The magnesian beds are bluer than the pure limestone. This limestone weathers to a deep soil and forms open valleys with few natural outcrops. The apparent thinning of the Beekmantown from west to east, particularly from Lancaster County to Northampton County, may be due to difficulties of measuring sections and failures to draw boundaries at the same horizons.

Water supply. The water-bearing properties of this limestone are much like those of the underlying formations. It may be a somewhat more favorable horizon because the purer limestones tend to be slightly more soluble than the dolomitic beds and hence become more thoroughly channeled and more promising as sources of water. Statistics, however, do not show this to be the case. Fifty-one wells ending in the Beekmantown limestone range in depth from 18 to 700 feet and have an average depth of 210 feet. Their reported yields range from less than 1 gallon to 200 gallons a minute and average about 25 gallons a minute. Three holes, 100, 500, and 600 feet deep were reported as being dry, and 19 of the 48 wells were reported to yield less than 6 gallons a minute. A description of the water-bearing properties of limestone, dolomite, and marble will be found on another page.

Six samples of water from this formation were analyzed, and all were found to be hard but none of them to contain much iron. The 6 samples range in total dissolved solids from 175 to 424 parts per million, in hardness from 159 to 344 parts per million, and in dissolved iron from only .06 to .23 part per million.

STONES RIVER LIMESTONE

General description. West of Susquehanna River the Beekmantown limestone is overlain by the Stones River limestone, which was named from Stones River in central Tennessee. This formation consists chiefly of pure limestone with some beds of magnesian limestone and ranges in thickness from 650 to 1,050 feet. In the Chambersburg-Mercersburg quadrangles this limestone can be divided into three members—at the base, massive pure limestone interbedded with magnesian layers; in the middle, massive subgranular pure limestone with thin beds of black chert and weathering into rectangular blocks; at the top, thin-bedded pure limestone. This formation is quite fossiliferous and gastropods (coiled shells) are numerous though usually rather poorly preserved. This limestone is the prized one for lime, and in the past was particularly sought after for use in local agricultural lime kilns.

East of Susquehanna River the Stones River type of high grade limestone continues as far as Womelsdorf, but fossils are scarce and the exact correlation with Stones River is not fully established. It is apparently absent east of Womelsdorf. The Stones River and overlying Chambersburg limestones are combined on the geologic map in this report (Plate 1).

Water supply. The Stones River limestone, on account of its being almost pure calcium carbonate, is somewhat more soluble than dolomite and contains numerous solution channels, which, when filled with water, may yield large supplies. Drillers frequently report openings in this limestone. The average depth of 24 wells in this limestone is 226 feet. Their average reported yield is 75 gallons a minute. The one sample of water analyzed from this formation is a typical limestone water, contains 258 parts per million of total dissolved solids and has a hardness of 234 parts. It contains only .05 part per million of dissolved iron. It represents a spring at Newville, Cumberland County.

CHAMBERSBURG LIMESTONE

General description. The Stones River limestone is overlain by a shaly impure limestone known as the Chambersburg limestone, named from the city of Chambersburg, where it is well exposed. It ranges from 100 to 750 feet thick in the Mercersburg and Chambersburg quadrangles. It extends southward into Maryland and West Virginia and northeastward to Carlisle, beyond which it thins rapidly eastwards and disappears near Mechanicsburg. This formation consists of a series of argillaceous limestone which becomes more and more shaly near the top, but at the base consists of compact limestone. Due to mud seams many beds weather cobbly, and form conspicuous outcrops. The Chambersburg limestone is not found east of Susquehanna River. On the geologic map in this report (Plate 1) it is combined with Stones River limestone.

Water supply. The water-bearing properties of this limestone resemble those of the more dolomitic layers at lower horizons rather than the underlying pure Stones River limestone. This limestone is not very soluble as a whole, and except for some of the purer beds which are somewhat cavernous, it is dense and tight and consequently a relatively poor water horizon. Small supplies can usually be obtained, but large industrial supplies can not ordinarily be procured. The water-bearing properties of limestones are described in page 41.

JACKSONBURG AND LEESPORT LIMESTONES

General description. In the area between the Delaware and Lehigh rivers and as far as Ironton to the west of the latter stream, the Beekmantown limestone is overlain by the Jacksonburg limestone, which is about equivalent to and closely resembles the Chambersburg limestone. It is better known locally as the "cement-rock formation" because of its use in the manufacture of Portland cement, the most valuable economic mineral product of the area. This formation varies in thickness from 250 to 600 feet, and in width of outcrop from a quarter of a mile to 2 miles. The Jacksonburg limestone consists of high-grade crystalline limestone The Leesport limestone is an argillaceous rock known locally as the "cement rock." In places these formations grade into each other. The contact between the Leesport limestone and the overlying Martinsburg shale, which in this area is usually slate, can be determined by the abrupt change in topography at the base of the steep slopes which mark the southern margin of the "slate belt." The region underlain by the Leesport "cement rock" is marked by low rolling hills while the areas underlain by the Jacksonburg "cement limestone" weather into flat valleys. The Jacksonburg limestone is usually very pure; that is, it runs high in calcium carbonate and low in magnesium carbonate, but some beds show a high percentage of the latter carbonate. This limestone ranges from 75 to 200 feet in thickness. The Leesport is a clayey deposit intermediate between limestone and shale. Its dark blue-black color and its slaty cleavage suggests the overlying slates as do the weathered fragments of light yellowish-gray color in the overlying soil. It is generally difficult to separate the slate and "cement rock" on account of the great similarity of the residual soils. This portion of the formation shows the results of the earth movements which shattered the dark blue beds and permitted the circulation of water, carrying mineral matter which was deposited in veins and irregular cavities. On account of the contrast in color between the white vein filling of quartz and calcite and the bluish-black background the veining is striking.

Southwest of Allentown a thin impure limestone that has been called Leesport "cement rock" occupies the position of the Jacksonburg limestone between the Beekmantown limestone and the Martinsburg shale. The few fossils collected from it, however, indicate an older age than Jacksonburg, but this is not fully established.

Water supply. The "cement rock" is dense, and the openings resulting from the shattering of the limestone have long since been closed up by water carrying mineral matter, with the result that the "cement rock" is a poor water horizon. However, small supplies adequate for domestic uses can usually be obtained from the zone of

weathered material and from cleavage openings. Large supplies can not, as a rule, be obtained from the "cement rock." In some of the quarries considerable volumes of water are encountered, but the rate of inflow is very small in comparison to the area of rock surface exposed in the quarries. The cement rock drills easily, and all drillers like drilling in it. When not too deeply covered it is wise to drill through the argillaceous upper beds into the underlying pure limestone, where the chances of finding a water supply are more favorable. The pure limestone is much more soluble and for that reason solution channels are more numerous. A number of successful wells in this formation apparently are drilled through the impervious upper beds into the underlying more favorable limestone. Five wells ending in the Jacksonburg limestone average 250 feet and yield about 70 g. p. m.

CONESTOGA LIMESTONE

General description. The Conestoga limestone, which is approximately equivalent in age to the Stones River limestone and the lower part of the Chambersburg limestone, overlies not only the Beekmantown but overlaps successively older beds down to and including the Harpers. This limestone, which is exposed throughout the Chester Valley, expanding to a wide belt in the vicinity of Lancaster, and extending southwest to the State line, is made of a basal coarse limestone conglomerate or breccias of blue limestone and white marble in a dark calcareous or argillaceous matrix, thin-bedded, blue argillaceous limestone, and dark graphitic slate. As might be expected with an overlapping formation, the conglomerates occur at or near the base of the formation. The thin-bedded argillaceous limestone typical of this formation and sometimes used as building stone is shown in Plate 5, B.

In the Great Valley, east of Susquehanna River, a similar impure limestone (the Leesport "cement rock") extends as far as Allentown. It has been described on a preceding page.

Water supply. The Conestoga limestone is somewhat dolomitic and shaly, and, in general, solution cavities are less numerous in it than in the Stones River. However, that channels do exist is shown by the large springs in this limestone south of Lancaster, and by the fact that a 1,000-foot well at Millersville yields less than 2 gallons a minute whereas another well only 110 feet distant and only 64 feet deep tested 20 gallons a minute. The latter well struck one or more water-bearing solution channels while the former is reported to have been drilled in solid limestone. The average depth of 64 wells ending in this limestone is 221 feet, and the range in depth is from 30 to 1,800 feet. Their reported yields range from less than 1 gallon to 300 gallons a minute and average about 28 gallons a minute. Five wells are reported to have very small yields. These unsuccessful wells range from 50 to 1,800 feet in depth.

Seven samples of water from the Conestoga limestone were analyzed. Six were obtained in Lancaster County, and one in Chester County. They are all moderately hard waters. Exclusive of one exceptionally hard water, the range is 230 to 311 parts per million in total solids and 187 to 274 in hardness. Six of the waters contain only .07 to .15 part per million of iron.

MARTINSBURG AND COCALICO SHALES

General description. The Chambersburg limestone in the west and the Jacksonburg limestone in the east are overlain by a series of shales which range in thickness from 2,000 feet in the western area to 3,000 feet in the eastern area, and are known as the Martinsburg shale, which was named from exposures at Martinsburg, W. Va. This formation consists of a lower black to gray, carbonaceous, fissile shale which, in the vicinity of Delaware River, has been metamorphosed to slate, and an upper yellowish green soft sandstone which grades into the overlying Juniata formation.[1] This shale weathers easily and fresh natural outcrops are rare except in valleys occupied by rapidly eroding streams, and sections suited for study must be sought in new railroad and highway cuts. The slate resists weathering for long periods of time and has a greater perfection of cleavage than the shale. East of Schuylkill River dynamic metamorphism of this shale increases until from the vicinity of Lehigh River eastward certain layers of the shale have been altered to slate of excellent quality.

In Lancaster County a formation that is probably equivalent to the Martinsburg shale rests on the Beekmantown limestone. It consists of blue, green, and purple, thin, fissile shales containing green arkosic (feldspathic) sandstone with glassy quartz grains with a dark blue crinoidal limestone at the base. The shale has a well developed cleavage and the sandstones aid in the study of the structural relations of this formation by indicating the true dip. The shale weathers rapidly to a thin soil filled with fine buff slivers. On account of the decided difference in lithologic appearance and its resting directly upon the Beekmantown limestone this shale was called the Cocalico shale, from exposures in the vicinity of Cocalico, Lancaster County, by Stose and Jonas[2]. This shale is mapped with the Martinsburg shale on Plate 1.

Water supply. While shale and slate are very different in lithologic characters, slate resembles a hard, brittle shale in water-bearing properties. In both, the rock itself is impervious and the water circulates through openings such as are found along joint and fault planes and bedding planes or planes of schistosity and not through pores in the rock. The slate, on account of the intense folding and the development of cleavage probably is a better source of water than the less thoroughly metamorphosed shale. Therefore, as a rule, wells in the slate obtain larger yields than those in the shale. As the total storage space is small, the water table fluctuates considerably with the season, and may drop 25 to 50 feet in dry years below its height in wet years. In the slate quarries considerable water is encountered, but the amount is not large as compared to extent of rock that is exposed. Surface drainage and precipitation over the quarry openings also contribute a considerable portion of the water. The water-bearing properties of the Cocalico shale are similar to the Martinsburg shale. Its restricted areal distribution reduces its importance as an aquifer and the data on five wells in Lancaster County have been combined with those from areas underlain by Martinsburg shale. The wells range from 60 to 500 feet in depth and average 194 feet. Two of the wells were reported to yield 10 gallons per minute and three to yield 20 gallons per min-

[1]Behre, C. H., Jr., Slate in Pennsylvania: Pa. Top. and Geol. Survey Bull. M 16, p. 136, 1932. Behre adds a third shaly division at the top containing the soft slate belt.

[2] Stose, G. W. and Jonas, A. I., The Lower Paleozoic section of Southeastern Pennsylvania: Jour. Wash. Acad. Sci., vol. 12, no. 15, pp. 358-366, 1922.

ute. In the shale drilled wells ranging in depth from 50 to 300 feet yield adequate domestic supplies. The following table summarizes the wells in this formation:

Summary of reported yields of wells in the Martinsburg and Cocalico shales in southeastern Pennsylvania.

	Number of wells with specified limits of depth, in feet					
	100 feet or less	101 to 200 feet	201 to 300 feet	301 to 500 feet	More than 500 feet	Total
Total number of wells on which information was obtained	45	27	14	12	4	102
Dry holes or wells with very small yield	2	0	0	0	0	2
5 gallons a minute or less	13	2	0	2	0	17
5+ to 20 gallons a minute	28	9	7	2	1	47
20+ to 100 gallons a minute	2	13	6	3	2	26
100+ to 200 gallons a minute	0	2	0	3	1	6
More than 200 gallons a minute	0	1	1	2	0	4

The average depth of these 102 wells is 150 feet and they range from 30 to 700 feet in depth. Their reported yields range from less than 1 gallon to 250 gallons a minute and average about 52 gallons a minute. As shown in the table, more than half of the wells yielded between 5 and 100 gallons a minute and more than half of them are less than 200 feet deep.

Wells in the slate are, in places, sufficiently strong to yield municipal and industrial supplies. A few flowing wells have been obtained by drilling into the slate where it is covered by glacial drift, but it is difficult to predict the localities in which artesian flows can be obtained.

In some areas the waters from the Martinsburg shale are rather hard but in others they are soft. Nine samples of water obtained from this formation were analyzed. They range in total solids from 35 to 266 parts per million and in hardness from 20 to 155 parts. Obviously, therefore, the Martinsburg shale waters are as a rule not so hard as the limestone waters but harder than the waters of the Cambrian quartzites and sandstones. Although only one of the 9 samples contained more than 1 part per million of iron and three had less than 0.1 part, water from shale generally carries more iron than water from limestone.

JUNIATA FORMATION

General description. In the southern part of the State the Martinsburg shale is overlain by the Juniata formation, which consists chiefly of red sandstone, shale, and conglomerate and is most conspicuously exposed along the Juniata River from whence it takes its name. On Plate 1 it is included with the Oswego sandstone, the lithology and water-bearing properties of which are not discussed in this report. These rocks form the upper slopes of Blue or North Mountain from Susquehanna River southwest, and where the slopes are not too steep or too heavily covered with talus from the overlying Tuscarora sand-

stone they are farmed. The red soils produced by this formation contrast in a striking manner with the drab fields underlain by the Martinsburg shale. The red shales usually weather down, with the result that only the sandstones outcrop in the fields, but exposures of both shale and sandstone can be found in steep cliffs along actively eroding streams and in railroad and highway cuts. The formation is 400 to 450 feet thick in the Mercersburg quadrangle, and thins eastward until at the Susquehanna it is about 200 feet thick and disappears before reaching Swatara Gap in Lebanon County. These sandstones are, in places, soft and porous while in others they are rather tightly cemented. Conglomeratic and cross-bedded layers are common near the base. This formation is considered to be of Silurian age by the Pennsylvania Geological Survey and Ordovician by the U. S. Geological Survey.

Water supply. This formation is of little importance as a water horizon because it outcrops usually in a narrow band in thinly inhabited regions where springs are adequate to care for the needs of the people. In the narrow water gaps relatively few springs issue from these beds. The one sample obtained from this formation for analysis is very low in mineral content and very soft. It was taken at Cove Gap, Franklin County.

SILURIAN AND DEVONIAN SYSTEMS

Rocks of Silurian and Devonian age, chiefly sandstone and shale with some limestone, overlie the Ordovician system and occur in small areas in the western part of Franklin County. These formations were not studied and no information was obtained as to their water-bearing properties.

MESOZOIC ROCKS

TRIASSIC SYSTEM

CHARACTER, DISTRIBUTION AND SUBDIVISIONS

The Triassic rocks described in this report are a part of the Upper Triassic Newark group. The Newark rocks in general are remarkably uniform in character. They comprise a great thickness of alternating sandstones and shales with subordinate amounts of other types of sediments. In large part they are reddish brown in color, and in many places they are cut by dikes and sills of diabase. The strata occur largely in great blocks that are tilted northwest and are separated from one another by normal faults with the upthrow mainly on the northwest side. The strata in greater part dip westward or northwestward, at angles from 10° to 35°, with an average of about 20°. In the vicinity of intrusive bodies of diabase, dips as high as 50° have been observed[1]. The total thickness of the system, computed from the dips and width of outcrops, is about 23,000 feet, but in no one place should the total thickness be found. The first sediments were deposited on the southern and eastern side of the elongated trough which deepened west and the later sediments were spread progressively farther west. Hence, only a fraction of the total thickness of these rocks should be encountered in any one place. The

[1] Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 9, 1929.

thickness of the beds may be increased by strike faults, but their presence was not observed in Pennsylvania west of Susquehanna River. In eastern Pennsylvania the Triassic beds mapped by Darton[1] in the Philadelphia folio are estimated to be between 10,000 and 13,000 feet thick. Darton mentions that he saw small faults which might increase the apparent thickness as determined from a study of dips and width of outcrop. However, his studies were made in an area where some of the upper beds had been removed by erosion. In the New Holland Quadrangle[2] the thickness of the New Oxford formation and Gettysburg shale is given as 25,000 feet and the thickness of an overlying conglomerate could not be determined from the exposure available for study.

The Newark group is believed to be of late Triassic age. Fossil plants, crustaceans, and vertebrates have been collected and compared with European forms. The fossils correspond within general limits but correlation of exact horizons in the American and European sections has not been feasible. The Newark rocks rest unconformably on older rocks, and do not share in the folding which took place at the end of the Carboniferous period; but on the other hand, these rocks are distinctly older than the Cretaceous deposits.

The Newark group of rock strata in Pennsylvania occupies a broad belt extending across the southeastern portion of the State from Delaware River to the Maryland State line south of Gettysburg. This belt is 32 miles wide on the Delaware, 4 miles wide in northern Lancaster County, 12 miles wide on the Susquehanna, and 14 miles wide at the Maryland State line. It is bounded by rocks of various kinds ranging in age from pre-Cambrian to Ordovician. In most places its northwest limit is determined by faults, and some of these marginal faults appear to be of great throw. Although over wide areas the dips are north and northwest, in some districts there are slight flexures of moderate amount and extent. In places the group is traversed by numerous normal faults, some of which extend northeast-southwest and others northwest-southeast.

In the rocks of the Newark group of southeastern Pennsylvania, as in most other regions, the typical red brown sandstone and shale predominate with subordinate amounts of gray, tan, buff, yellow, green, and black sedimentary rocks as well as relatively small amounts of dark colored igneous rocks, chiefly diabase. The divisions which have been established in New Jersey are applicable only a short distance west of the Schuylkill. They are the Stockton formation, the Lockatong formation, and the Brunswick shale, the last named being the youngest. To the westward they are divisible into the New Oxford formation below and the Gettysburg shale above. There are many conglomerates, mostly in the upper formation, most of which are quartzose but some are limestone conglomerates. The larger of these are separately mapped.

The sediments of the Newark group have been altered adjacent to the intrusive sills and dikes of diabase. The degree of alteration is, in general, dependent upon the size of the intruding mass. The shales and sandstones are unaltered within a few feet of the narrow

[1] Bascom, F. and others, U. S. Geol. Survey Geol. Atlas, Philadelphia folio, (No. 162), p. 7, 1909.

[2] Jonas, A. I., and Stose, G. W., Topographic and Geologic Atlas of Pennsylvania, No. 178, New Holland Quadrangle, p. 17, 1925.

dikes but the larger dikes and sills altered the adjacent sediments for hundreds of yards. The alteration consists of baking and, frequently, in a change of color. The baked rocks are usually hard and resistant and, in places, were more resistant than the intruding diabase. The baked rocks are less pervious, as a general rule, than the unaltered sediments.

DESCRIPTION OF FORMATIONS

STOCKTON AND NEW OXFORD FORMATIONS

The Stockton formation, the basal Triassic formation in the eastern part of the State, lies on gneiss, schist, quartzite, and limestone in Montgomery, Bucks, and northern Chester counties. It consists chiefly of coarse, more or less disintegrated arkosic conglomerate, yellow micaceous felspathic sandstone, brownish red sandstone, and soft red shale. The red beds give the dominant color tone to the rocks, but the yellow, gray, green, and black are relatively thick but rather inconspicuous. These different kinds of rocks are interbedded in no regular sequence, and are frequently repeated. Cross-bedding is a conspicuous feature in the sandstone and ripple marks, mud cracks, and raindrop impressions are common in the shales and shaly sandstones, which indicate shallow water conditions during deposition. This formation has a well developed system of joints and is much faulted. The soil from these rocks is usually deep and under careful cultivation yields large crops. Except in artificial exposures, such as quarries and railroad and highway cuts, rock outcrops are not numerous. In these cuts the sandstones usually resist weathering, but the shales although firm when first exposed to the elements quickly succumb and alter to a red sandy clay which slumps. The thickness of the Stockton formation is approximately 4,000 feet near Norristown, Montgomery County. However, computations from dips and widths of outcrop give a thickness of about 6,000 feet. A deduction of 2,000 feet was made on account of supposed repetitions[1].

The lower beds from Elverson to Gettysburg were given the name of New Oxford[2] formation, from the town of New Oxford, Adams County, in the vicinity of which it is well exposed. The red shale and sandstone contain many beds of light-colored micaceous sandstone, arkose, and conglomerate. The coarser sediments are found in the lower 3,000 feet while the upper 4,000 feet consists of finer materials, chiefly shales and micaceous sandstones. The upper limit of the formation is drawn where the micaceous harder sandstones cease to be prominent, and the softer shales become dominant. Consequently, the upper limit is somewhat indefinite and the boundary line may not be exactly at the same stratigraphic horizon at all points. The thickness of the formation as determined from a composite section is about 7,000 feet.

LOCKATONG FORMATION

The Lockatong formation consists mostly of dark, hard shales and flagstones. It thins out a short distance west of the Schuylkill. The shales range from dark gray to black, and split readily parallel to the bedding, but lack a true slaty cleavage. The argillites are usually

[1] Bascom, F. and others, U. S. Geol. Survey Geol. Atlas, Philadelphia folio, (No. 162) p. 7, 1909.

[2] Stose, G. W., and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 9, 1929.

black to bluish purple while the flagstones are dark gray to green. Dark red shale resembling flagstones and some highly calcareous shales occur in beds of different thickness and without any definite sequence. In general the beds are essentially fine-grained rocks and consist of a mixture of clay and fine sand in variable proportions. None of the sandstone is free from mud, nor are the shales entirely free of sand so that it is difficult to draw a line separating sandy shale and shaly sandstone. Minute calcite and pyrite crystals are numerous in some of the argillite beds but are absent in others.

Ripple marks and mud cracks indicate that the rocks were formed in shallow waters, and were even uncovered at times, but the water currents must have been gentle, as is shown by the absence of coarse sediments.

This formation is reported[1] to be about 3,600 feet thick at Sourland Mountain in New Jersey but it thins rapidly to the south and west. It is only 1,800 feet thick at Ewingville and Princeton, New Jersey. Darton[2] gives a thickness of 3,000 feet just east of Perkiomen Creek, but makes no allowance for repetition by faulting. The thickness decreases in eastern Pennsylvania until the formation disappears east of Elverson, Chester County.

BRUNSWICK AND GETTYSBURG SHALES

The Brunswick shale is present in the eastern part of the State and consists of soft shales with subordinate local sandstones. The rocks are chiefly red although purple, green, yellow, and black layers occur. These shales lack the strength of the beds in the underlying formations and weather rapidly to minute fragments or split into thin flakes. In places lens and beds of green shale are conspicuous. Mica is a prominent constituent of the shales in some localities and where present in quantity, usually causes the layers to split evenly along the bedding planes. As a result of the generally soft character of these shales the Brunswick shale weathers more easily than the underlying Triassic formations, and forms smooth valleys which contrast with the hilly country produced by the more resistant layers in the Lockatong and Stockton formations. The soil is usually good and the farmers are prosperous.

Abundant ripple marks, mud cracks, and raindrop impressions indicate that the sediments accumulated in shallow water and were at times exposed to subaerial conditions. In some beds plant remains, usually carbonized, are found, and in others reptile tracks occur.

In Bucks, Lehigh, and Montgomery counties in eastern Pennsylvania large extrusive sheets of basalt are interbedded with the Brunswick shale. Erosion has removed some of the overlying sedimentary beds and these sheets outcrop in large areas in these counties. At the top of this formation in Bucks and Lehigh counties there is a basalt conglomerate. It resembles the fanglomerate found in the Brunswick and Gettysburg shales except the pebbles are composed of basalt instead of quartzite or limestone.

The thickness of the Brunswick shale is estimated by Darton and

[1] Bascom, F., and others, U S. Geol. Survey Geol. Atlas, Trenton folio (No. 167), p. 7, 1909.

[2] Bascom, F. and others, U. S. Geol. Survey Geol. Atlas, Philadelphia folio, (No. 162), p. 8, 1909.

Kümmel[1] to be 12,000 to 15,000 feet in New Jersey and extreme eastern Pennsylvania.

West of Elverson, Chester County, these red shales and sandstones are known as the Gettysburg shale, the type locality of which is Gettysburg[2] and vicinity. The Gettysburg shale, like the Brunswick shale, has been invaded by a great sill of diabase, which extends with interruptions through Adams, York, Lancaster, Dauphin, and Lebanon counties. Connected with the sill are a number of cross-cutting bodies, dikes and smaller sills. The intrusives have altered the sediments and the bright red shales have been changed to dull red on the outer edges of the metamorphosed zones, becoming harder and dark toward the contact with igneous rock until at the contact it is a dark purple to almost black argillite. The more calcareous beds have been altered to a light colored, generally porous porcellanite. The sandstone beds which have been altered by heat from the intrusive bodies are light buff and porous.

This shale can be divided into three members. The lower member consists chiefly of red shales with interbedded soft red sandstones and minor amounts of white sandstone, green and yellow shale, black carbonaceous shale and dark impure limestone. The total thickness of this member is about 7,500 feet inclusive of the diabase sill. The middle member, called the Heidlersberg member from the conspicuous outcrops in the vicinity of that town[3], consists chiefly of red shale and sandstone with some green, gray and black shales, interbedded with numerous harder gray to white sandstones which separate it from the overlying and underlying members. The thickness of this member is approximately 4,800 feet. The upper member consists of approximately 3,500 feet of soft red shales, which in most places are poorly exposed. The total thickness of the Gettysburg shale in Adams County is about 16,000 feet.

Both the Brunswick shale and the Gettysburg shale contain considerable conglomerate at the top of the section. It is chiefly fanglomerate and is composed of more or less rounded pebbles which were derived from the land masses to the north and west of the troughs. These highlands were uplifted late in the period of deposition of the sediments in the troughs. These highlands contributed pebbles ranging in size from a fraction of an inch to many inches in diameter. The rounding of the pebbles was dependent upon the distance the pebbles traveled. They differed in character depending upon the types of rocks composing the highlands from which they were derived. The pebbles consist of such diverse materials as limestone, quartz, quartzite, aporhyolite and metabasalt. The most important types are the quartzose and limestone conglomerates which are shown on the geologic map. See Plate 1. The areas mapped as quartzose conglomerate are composed not only of the quartz and quartzite pebbles set in a red matrix but also of metabasalt and aporhyolite. The areal extent of these conglomerates composed of the volcanic rocks is small and is confined to small areas in Adams County. The limestone conglomerates which are known locally as "calico rock"

---

[1] Bascom, F., and others, U. S. Geol. Survey Geol. Atlas, Trenton folio, (No. 167), p. 8, 1909.

[2] Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio, (No. 225), pp. 9-10, 1929.

[3] Stose, G. W. and Bascom, F., loc. cit. p. 10.

and "Potomac marble" consist of limestone pebbles derived from the Cambrian and Ordovician limestones and dolomites. The pebbles are commonly set in a matrix of sandy red argillaceous to calcareous red rock. The exposures of the conglomerates are generally badly weathered. The matrix usually disintegrates rapidly and the pebbles except the calcareous are more resistant to weathering and accumulate as loose gravel and boulders. The calcareous pebbles frequently disappear; the carbonates are removed by solution and the insoluble clayey portions remain.

WATER SUPPLY OF THE SANDSTONES AND SHALES

On account of the general similarity of the strata of the Newark group, they will be discussed as a unit with respect to their water-bearing properties. The sandstones and the conglomerates can be relied upon to yield the largest supplies, while the shales usually yield the smallest.

The conglomerates which occur in the lower parts of the Stockton and New Oxford formations appear to be better aquifers than the fanglomerates at the top of the Brunswick and Gettysburg shales. The conglomerates in the lower formations have a large areal extent and the matrix of the conglomerate is apparently more permeable while the fanglomerates are more restricted in areal extent and the pebbles are set in a denser matrix. However, where the sandstones are thoroughly cemented and have only few joints they do not yield the supplies that one normally expects to obtain from them. On the other hand, where the shales are closely jointed they may yield unexpectedly large supplies. Again the changes in the character of many beds from place to place make it difficult to predict for any given locality the depth at which a supply will be encountered or the quantity of water that will be found. In general, the largest supplies are obtainable from the coarser beds in the Stockton and New Oxford formations, where wells from 6 to 10 inches in diameter and 200 to 500 feet deep obtain as much as 200 gallons a minute, or more. However, in some areas the beds are more thoroughly cemented or the sediments are finer-grained so that some wells yield little or no water. The dense beds of the Lockatong formation and the Brunswick and Gettysburg shales usually yield only small supplies sufficient for domestic use. A number of old dug wells ranging in depth from 10 to 100 feet are still in use, and some of these rarely or never go dry, although they show considerable fluctuations in their water levels. The following tables summarize the data on wells in the Triassic formations:

Summary of depths and yields of wells in the three Triassic formations in southeastern Pennsylvania.

Formation	Number of wells	Range in depth in feet	Average depth in feet	Range in yield in gallons a minute	Average yield in gallons a minute
Brunswick and Gettysburg shales	112	18–500	157	0–300	41
Lockatong formation	53	37–511	151	0–60	13
Stockton and New Oxford formations	67	35–731	174	0–349	57
All Triassic sandstones and shales	313	18–1005	171	0–349	38

Summary of reported yields of wells with specified limits of depth in Triassic sandstones and shales in southeastern Pennsylvania.

	Number of wells with specified limits of depth, in feet					
	100 or less	101 to 200	201 to 300	301 to 500	More than 500	Total
Total number of wells on which information was obtained	132	94	44	35	8	313
Dry holes or wells with very small yield	1	2	5	0	1	9
5 gallons a minute or less	32	16	4	3	1	56
5+ to 20 gallons a minute	88	46	8	3	2	147
20+ to 100 gallons a minute	11	26	17	15	2	71
100+ to 200 gallons a minute	0	2	9	8	1	20
More than 200 gallons a minute	0	2	1	6	1	10

As shown in the above tables, wells in the Stockton and New Oxford formations have the greatest average yield and those in the Lockatong formation the lowest. About two-thirds of all the wells in the Triassic sandstones and shales yield between 5 and 100 gallons a minute. More than two-thirds of the total wells in Triassic rocks in regard to which information was obtained are less than 200 feet deep, and more than half of these yield between 5 and 20 gallons a minute.

Where wells extend through a considerable thickness of shale it is wise to case them down to the water-bearing horizon. In uncased wells the shale wells are likely, in the course of time, to crumble and slump in, causing the water to become muddy and the well to fill with mud.

Thirty-three samples of water obtained from wells and springs in the Triassic sedimentary rocks were analyzed, and the results of the analyses are given in the table at the end of this report. These analyses show that the Triassic waters average nearly as high in total dissolved solids as the limestone waters and also in hardness, and many of them contain much more iron than is commonly found in the limestone waters. The Triassic waters, however, are much more variable than the limestone water, and range, in the samples analyzed, from very soft and low in mineral content to the hardest and most highly mineralized waters obtained from the area.

Although there is much irregularity in the mineral content of the waters in each of the recognized Triassic formations, the samples obtained from the Stockton and New Oxford formations average distinctly lower in total dissolved solids, hardness, and iron content than those obtained from the Lockatong formation and Brunswick and Gettysburg shales (see table following). This is fortunate because the Stockton and New Oxford formations also as a rule yield the largest quantities of water.

Summary of total dissolved solids, hardness and iron content of the different formations of the Triassic system in southeastern Pennsylvania, in parts per million.

	Number of analyses	Total dissolved solids		Hardness		Iron	
		Range	Average	Range	Average	Range	Average
Brunswick and Gettysburg shales	6	201 to 786	363	152 to 499	251	.05 to 4.9	[a].20
Lockatong formation	7	199 to 1,050	418	162 to 533	285	.06 to 17	[b].17
Stockton and New Oxford formations	8	100 to 570	211	46 to 381	136	.05 to .10	.07
All Triassic sedimentary rock (sandstone, shale, etc.)	33	44 to 1,106	299	14 to 557	196	.01 to 17	[c].18
Triassic diabase or trap rock	4	66 to 333	176	31 to 243	114	.04 to .20	.15

[a] Exclusive of one sample which contained 4.9 parts.
[b] Exclusive of one sample which contained 17 parts.
[c] Exclusive of two samples which contained respectively 4.9 and 17 parts.

TRAP ROCK OR DIABASE

General description. Diabase is an intrusive igneous rock which is widespread in occurrence. In southeastern Pennsylvania outcrops of this rock are numerous, and the best known masses are the Conshohocken dike in the eastern part of the State, the large areas near Quakertown and Birdsboro, and the Gettysburg sheet in the vicinity of the borough by the same name. Diabase occurs in dikes and sheets or sills. Dikes are nearly vertical and cut across the sedimentary strata. Sheets or sills are layers which follow the bedding and have a gentle dip. Dikes vary in width from a few inches to a hundred feet, or more, but dikes exceeding 100 feet in width are not numerous. Some sheets are several hundred feet thick and the Gettysburg sheet is 1800 feet thick. The length of the diabase dikes, considering their thinness, is in some cases phenomenal. Dikes which do not exceed 75 feet in width stretch for miles across the country. The longest dike is probably the one that comes in from Maryland, crosses the belt of Triassic rocks west of Gettysburg in Seminary Ridge, crosses the east end of South Mountain and Cumberland Valley east of Carlise to North Mountain, a length of about 50 miles in Pennsylvania (see Plate 1). There are several dikes more than 30 miles in length. Owing to the greater resistance to erosion of the diabase compared with the unaltered enclosing rocks, the dikes stand out as conspicuous ridges, usually tree-covered because the residual boulders of diabase are so numerous that the land cannot be profitably utilized for other purposes. The adjacent part of the enclosing rock is generally hardened, or baked, by the heat of the intruding diabase, and is sometimes more resistant to erosion than the diabase itself. These zones of hardened rock materially increase the width of the ridges.

This trap-rock exhibits a remarkably uniform character, weathering into boulders which are readily recognized by a rusty-yellow, oxidized coat and greenish-gray interior and a conchoidal fracture on fresh

surfaces. The only feature which shows great variation is the size of the mineral grains, which depends on the rate at which the igneous material that produced the rock was cooled. In some of the dikes the rock is dense and exceedingly fine-grained, but in the thicker ones, where cooling proceeded more slowly, the texture is coarse and the rock almost resembles granite. The rock consists essentially of plagioclase and augite in practically equal amounts, with ilmenite, quartz, and apatite as accessory minerals. During the process of weathering chlorite, calcite, epidote, and a little biotite developed.

The diabase cuts Triassic rocks and is Triassic in age, but it occurs as intrusions in rocks of every age from the Baltimore gneiss to the Triassic.

Water supply. The dikes probably do not greatly affect the movement of the ground water except in the Triassic rocks. Most of the rocks intruded are dense rocks in which the greater part of the circulation of ground water depends on fissures, joints, and crevices. The dikes doubtless act as barriers to the water in the porous Triassic sandstones but to some extent the water can escape through the joints by which they are broken.

Although the diabase is regarded as a poor formation as a source of water, nevertheless it does yield some water. Springs are common in ravines crossing the dikes, and wells drilled into the dikes usually yield small but unfailing supplies. Diabase is very impervious but the upper part is usually deeply weathered, and from the weathered material most wells draw their supplies. The 12 wells ending in diabase in regard to which information was obtained, range in depth from 16 to 125 feet, and average 52 feet. Most of these probably end in the zone of disintegrated rock and do not penetrate the fresh solid rock. The average reported yield of these was 6 gallons a minute and the range in yield was from 3 to 13 gallons a minute.

The water from the diabase is generally considered satisfactory by the people who use it. The analyses of 4 samples from Adams, Bucks, and York counties of water obtained from diabase are given in the table at the end. The waters analyzed range from rather low to moderately high in total dissolved solids. They are all low in iron; two of them are essentially soft waters and the other two are moderately hard. The two hard waters are relatively high in sulphate and have considerable sulphate hardness, which can not be removed by heating.

CRETACEOUS SYSTEM

General description. The Cretaceous system is represented in southeastern Pennsylvania by beds of sand and clay which rest unconformably on the eroded surfaces of the pre-Cambrian metamorphic and igneous rocks. These beds are exposed only in small areas too small to show on the geologic map in the vicinity of Philadelphia where only the Raritan and Patapsco formations have been definitely recognized. They are elsewhere covered by Quaternary deposits. A few scattered areas of clay of probable Cretaceous age overlie the Paleozoic limestone of Chester Valley north of Philadelphia.

The Patapsco formation consists of sediments that apparently were deposited in an embayment at the mouth of the ancient Schuylkill River. It is composed chiefly of highly-colored, variegated clays which

are ferruginous and very plastic. At the base, however, in wells, is a bed of coarse yellow sand which may be the equivalent of the Patuxent formation.

The Raritan formation, which overlies the Patapsco formation, is 150 to 200 feet thick in wells and consists of light-colored sands and clays. The beds vary in character both vertically and laterally, the sand passing into the clay, and vice versa, within short distances. The formation lacks the high coloring and variegation of the underlying Patapsco.

Water supply. The bed of coarse yellow sand (Patuxent formation) at the base of the Patapsco formation in wells is an excellent source of water and is extensively utilized in the southern part of Philadelphia in wells which pass through the Quaternary gravels at the surface. Wells ending in it yield large supplies, a few of them furnishing more than 500 gallons a minute. The clay yields very little water, but the sand is the source of the largest supplies of ground water in southeastern Pennsylvania. The 24 wells in the Patapsco formation on which information was obtained range in depth from 33 to 250 feet and average about 118 feet. They range in reported yield from 30 to 800 gallons a minute and average about 217 gallons a minute. The depths of wells in this formation is probably not related to their yields, but instead shows only the distance the water-bearing horizon lies below the surface.

The Raritan formation yields some water but is not depended upon for large supplies. All drillers seeking industrial supplies should endeavor to reach the basal sands of the Patapsco formation.

CENOZOIC ROCKS

TERTIARY (?) ROCKS

PLIOCENE (?) SERIES

BRYN MAWR GRAVEL[1]

General description. The Bryn Mawr gravel which, on Plate 1, is mapped with the Brandywine formation, of Pleistocene age, is probably Pliocene in age. The gravel caps hills in Montgomery, Philadelphia, Chester, and Delaware counties. The most extensive area contains less than three square miles and many remnants of this probably once extensive deposit are too small to show on Plate 1. The gravel consists of well rounded quartz pebbles cemented more or less firmly by the hydrated oxides of iron into a conglomerate known locally as "ironstone." The type area is at Bryn Mawr, Lower Merion Township, Montgomery County. The lowest areas covered by this gravel are at an altitude of approximately 300 feet in Delaware County and rise northwestward to an elevation of 480 feet. The larger part of the existing areas lie at an elevation of approximately 400 feet.

Water supply. The Bryn Mawr gravel on account of its restricted areal distribution, of its thinness, and its elevated position favorable to drainage is unimportant as a source of ground water.

[1] Bascom, F., The resuscitation of the term Bryn Mawr gravel: U. S. Geol. Survey Prof Paper 132, pp. 117–119, 1924.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

BRANDYWINE FORMATION[1]

General description. The Brandywine formation is mapped with the Bryn Mawr gravel on Plate 1. It originally included all the higher gravels in the area covered by this as well as in adjacent areas. Bascom[2] separated the Brandywine formation into two levels and in 1924 proposed[3] that the upper level be called Bryn Mawr and the term Brandywine be restricted to the lower level. The formation is present in Delaware County at elevations slightly above 220 feet. It consists of sand and gravel with some cobbles. The material is not ordinarily well cemented. The Brandywine formation is unimportant as a source of ground water.

SUNDERLAND, WICOMICO, AND TALBOT FORMATIONS

General description. The post-Brandywine Pleistocene deposits of the Coastal Plain are usually divided into three formations, the Sunderland, Wicomico, and Talbot, which terraces bear the same names. The formations are composed of sand, gravel, boulders, and clay. Fossils are not common, and those found are not sufficiently diagnostic to separate the terraces, nor can they be separated on the basis of lithology on account of their similarity. These formations are shown as sand and gravel on Plate 1. The oldest of these three formations is the Sunderland. It caps the highest of the three terraces and is now restricted to a few isolated patches. The two younger formations cap more or less continuous terraces that lie at lower levels along the Delaware River with re-entrants at the larger tributaries. In this area, these formations are all thin and in many places even the smaller tributary streams have cut through them into the underlying rocks.

The Sunderland formation, named from Sunderland, Calvert County, Maryland, where it is well developed, is the highest and oldest of the Columbia group. It consists of sand, gravel, boulders, clay, and loam, and caps uplands at elevations of approximately 160 to 220 feet above sea level in isolated patches in parts of Delaware County, near Valley Forge in Chester County, and in the vicinity of Conshohocken in Montgomery County. Terrace deposits which may be equivalent to the Sunderland are also found along the Delaware River in Northampton County. These latter deposits are more or less intimately associated with glaciation. These isolated patches are remnants of an apparently widespread formation which has been greatly reduced in areal extent both by wave erosion in the cutting of the young terraces and by stream erosion subsequent to uplift.

The Wicomico (Pensauken) formation on the Wicomico terrace next below the Sunderland terrace, ranges in elevation from 60 to 120 feet above sea level. The formation and the terrace receive their name from Wicomico County, Maryland, where they are well developed. The formation consists of sand, gravel, boulders, clay, loam, and some lignitic material. The character of the deposits changes

[1] Clark, W. B., The Brandywine formation of the Middle Atlantic Coastal Plain: Am. Jour. Sci., 4th ser., vol. 40, p. 499, 1915.

[2] Bascom, F., U. S. Geol. Survey Geol. Atlas, Elkton–Wilmington folio, (No. 211), p. 4 and 12, 1920.

[3] Bascom, F., loc. cit, p. 118, 1924.

rapidly from place to place and sand and clay replace each other within short distances. In places the material is very poorly assorted. The Wicomico formation forms a broad terrace which ranges up to 3 miles in width, and roughly parallels Delaware River. Erosion has attacked the formation and the streams have cut through the soft sediments to the underlying rocks so that in some areas a once continuous belt is separated into a series of isolated patches of different sizes. In the interstream areas the formation underlies broad flat terraces which slope gently up from the scarp dividing the Wicomico and Talbot terraces. Along the streams where erosion is active the surface of the terrace is undulating.

In most places the formation is less than 10 feet thick and hence is too thin to be of much value as a source of water supplies. In the vicinity of Boothwyn, Delaware County, the formation is thicker and consists chiefly of sand and gravel that yield considerable volumes of water.

The Talbot (Cape May) formation and terrace take their name from Talbot County, Maryland, where this terrace and its capping are well developed. The terrace level rises from nearly the level of Delaware River to an elevation of about 40 feet above the river. This terrace in some places rises gently from the water's edge but in other places it has a well developed wave-cut cliff 8 to 10 feet high. The terrace varies in width on the Pennsylvania side of the Delaware from 1 to 4 miles, the greatest expansion being in the southern part of Philadelphia, and at the great bend in Delaware River below Morrisville and Trenton. The Talbot formation consists of sand, clay, gravel, boulders, and peat. These materials grade rapidly laterally and vertically into each other so that sand replaces clay within short distances. The materials are relatively fresh and show few signs of disintegration, indicating that this terrace is distinctly younger than the Wicomico. Streams crossing this terrace usually have not modified its surface except in certain localities. The terrace, which is not so strikingly developed in Pennsylvania as in Delaware, is wave cut, and the deposits were brought in by inflowing streams and distributed by currents when the sea level was somewhat higher than at present. The deposits rest in places on the pre-Cambrian rocks, and in others on the Lower Cretaceous deposits. The Talbot formation rarely exceeds 15 feet in thickness.

In many places along Delaware River this terrace is the scene of industrial plants and areas of dense population so that the ground water is likely to be badly polluted. The formation contains water-bearing sand and gravel but is too thin to yield the large supplies needed for industrial plants. In the less densely inhabited localities shallow dug wells will yield small supplies for domestic use. It is suggested that the wells be dug some distance below the contact with the underlying formation because the largest volume of water is usually obtained at or near the contact and also because that part of the well that extends below the water table will fill during periods when no water is pumped and thus will afford storage, making considerable volume of water available when needed.

Water supply. Information on only 7 wells in the Pleistocene gravels was obtained. They average 91 feet in depth and range from 22 to 160 feet. Their average reported yield was 49 gallons a minute, ranging from less than 1 gallon to 100 gallons a minute.

In most places the three formations are thin and occur in isolated patches. For these reasons they are not important as sources of water.

GLACIAL DEPOSITS

General description. The glacial deposits[1] of this area are confined to a portion of Northampton County where both stratified and unstratified deposits are present. The terminal moraine crosses Delaware River at Belvidere, and thence extends westward to Nazareth Junction and northwestward to Pen Argyl. West of Pen Argyl it is traced with difficulty. Lewis traced its path across Blue Mountain eastward of the Big Offset, but the deposits along the mountain from Pen Argyl to the Wind Gap are glacial in character, as are those in the gap. West of Wind Gap the deposits on the south flank of the mountain appear to be glacial, but they are thin and the locality lacks the appearance of either an outwash plain or a terminal moraine. The terminal moraine consists of unsorted sand, clay, and boulders of many types of material, ranging in size from boulders 20 feet across, near Ackermanville, to the finest clay.

Apparently some traces of an older or Jerseyan glaciation also occur in this region. The areal extent of the glacial deposits is not shown on the map, only the southern limit of each of the several sheets of drift is delineated.

Water supply. Ten wells in these deposits range in depth from 34 to 150 feet and average 96 feet. They range in reported yield from 3 to 150 gallons a minute and average about 64 gallons a minute. Two samples of water from the glacial drift that were analyzed are low in total dissolved solids and in iron. One of them is distinctly soft and the other has only very moderate hardness. (See the analyses from Northampton County.)

SUMMARY OF WELLS BY GROUPS OF FORMATIONS

The formations having similar water-bearing properties have been grouped together to permit comparisons of depths and yields.

The following table gives the percentage of wells within specified limits of depth in the several formations or groups of formations:

Summary of percentage of wells with specified limits of depth in the several groups of formations in southeastern Pennsylvania.

Formation or groups of formations	Total number of wells	Depth in feet: 100 or less	101 to 200	201 to 300	301 to 500	More than 500
		Per cent	Per cent	Per cent	Per cent	Per cent
Pre-Cambrian gneiss, schist, and phyllite	329	51	26	9	9	5
Igneous rocks	129	81	16	2	1	1
Setters, Chickies, and Hardyston quartzites	46	46	20	17	7	11
Limestone, dolomite and marble	345	35	32	17	9	7
Martinsburg shale	87	41	26	14	14	5
Triassic sandstones and shales	313	42	30	14	11	3
Patapsco formation	24	46	50	4	0	0
Glacial drift	10	50	50	0	0	0
Surficial deposits	7	71	29	0	0	0

[1] Lewis, H. C., Terminal moraine in Pennsylvania and western New York; Pennsylvania Second Geol. Survey, Report Z, 1884.

A large part of the wells on which information was obtained are 100 feet or less in depth. If records of all the wells that have been drilled in the region were available the percentage of shallow wells would probably be still higher.

The following table gives the percentage of wells with specified limits of yield in the several formations or groups of formations:

Summary of percentage of wells with specified limits of yield in the several groups of formations in southeastern Pennsylvania.

Formation or groups of formations	Total number of wells	Yield in gallons a minute					
		Dry or very small yield	5 or less	5+ to 20	20+ to 100	100+ to 200	More than 200
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Pre-Cambrian gneiss, schist and phyllite	329	3	24	48	24	1	0
Igneous rock	129	3	50	34	12	1	0
Setters, Chickies and Hardyston quartzites	46	4	20	43	26	4	2
Limestone, dolomite and marble	345	6	19	33	29	8	5
Martinsburg shale	87	3	13	33	25	9	4
Triassic sandstones and shales	313	3	18	47	23	6	3
Patapsco formation	24	0	0	0	38	29	33
Glacial drift	10	0	20	30	30	20	0
Surficial deposits	7	14	86	0	0	0	0

About half of the wells ending in igneous rock yield 5 gallons a minute or less whereas the highest percentage of wells of most of the other formations or groups of formations falls in the 5 to 20 gallons a minute limit. The figures given for the surficial deposits may not be truly representative because of the small number of wells recorded. It is worthy of note that 6 per cent of the wells in limestone, dolomite, and marble are reported as dry or of very small yield.

The following table gives the average reported yields of wells with specified limits of depth in the several formations or groups of formations:

Summary of average reported yields of wells with specified limits of depth in the several groups of formations in southeastern Pennsylvania, in gallons a minute.

Formation or groups of formations	Total number of wells	Depth in feet				
		100 or less	101 to 200	201 to 300	301 to 500	More than 500
		g.p.m.	g.p.m.	g.p.m.	g.p.m.	g.p.m.
Pre-Cambrian gneiss, schist, and phyllite	329	14	19	24	45	41
Igneous rock	129	11	18	17	70	60
Setters, Chickies, and Hardyston quartzites	46	23	40	58	25	35
Limestone, dolomite, and marble	345	35	40	86	131	173
Martinsburg shale	87	8	73	63	110	73
Triassic sandstones and shales	313	12	30	75	110	47

The above table shows that in general with increasing depth, there is a corresponding increase in yield up to a depth somewhere between 300 and 500 feet, beyond which depth the average yields decrease. For the quartzites, this maximum average yield occurs between depths of 200 and 300 feet. For the limestones, dolomites, and marbles, there is a steady increase in yield with increase in depth. It is doubtful whether the above generalization represents the true relations because most of the shallower wells are drilled to supply domestic needs and they are therefore often not tested to maximum capacity. Many of the deeper wells are drilled to provide industrial supplies and most of them are therefore tested to maximum capacity.

The following table summarizes the depths and reported yields of all wells in southeastern Pennsylvania on which information was obtained:

Summary of depths and yields of wells in the several formations or groups of formations in southeastern Pennsylvania.

Formation or groups of formations	Number of wells	Range in depth in feet	Average depth in feet	Range in yield in gallons a minute	Average yield in gallons a minute
Pre-Cambrian gneiss, schist, and phyllite	329	30–1,825	172	0– 150	21
Igneous rocks, including gabbro, serpentine, diabase, granite, and pegmatite	129	16–1,000	84	0– 120	13
Setters, Chickies, and Hardyston quartzites	46	30–1,069	210	0– 225	34
Limestone, dolomite, and marble	345	18–1,800	199	0–1,450	63
Martinsburg shale	87	30– 700	198	0– 250	51
Triassic sandstones and shales	313	18–1,005	171	0– 349	38
Patapsco formation	24	33– 250	118	30– 800	217
Glacial drift	10	34– 150	96	3– 150	64
Pleistocene terrace deposits	7	22– 160	91	0– 100	49
All other formations	17	60–1,320	309	5– 65	24
Total of all formations in the region	1,307	16–1,825	173	0–1,450	42

The above table shows that the igneous rocks are the poorest sources of water in the region, averaging 13 gallons a minute. The average depth of wells in these rocks is also the least of any of the groups of formations. The Patapsco formation has the highest average reported yield. It is to be noted that in each of the formations or groups of formations, dry holes or wells with very small yield may occur. The Patapsco formation and the glacial drift may be exceptions to this statement.

MINERAL MATTER DISSOLVED IN THE WATER

A total of 144 samples of water from wells and springs were collected. They were analyzed by Margaret D. Foster and Charles S. Howard, in the water-resources laboratory of the U. S. Geological Survey, for their contents of dissolved mineral matter. An effort

was made to obtain representative samples from all the principal water-bearing formations and from every section of the area under investigation. The results of the analyses are shown in the tables at the end of the report.

The maximum and average figures for the different constituents in the waters from any formation are affected greatly by the chance collection of one or two unusual samples and may possibly lead to unreliable conclusions as to the general characteristics of waters usually obtained from the formation. It is certain that many of the waters analyzed are not truly representative of the formations in which the wells end. They may be too lightly mineralized because they have come to the well quickly through fissures, or they may carry unduly large quantities of dissolved mineral matter as a result of passing through more soluble formation. They may carry abnormally large quantities of some constituents which have reached the sources of the waters as a result of human activities.

The ground water in southeastern Pennsylvania generally does not contain large amounts of dissolved mineral matter. Of the 144 samples of water that were analyzed, only 2 contain more than 1,000 parts per million, or one-tenth of 1 per cent, of total dissolved mineral matter, and only 10 contain more than 500 parts per million. On the other hand, 46 of these waters, or about a third of the total, contain less than 100 parts per million and 7 contain less than 25 parts.

The larger quantities of mineral matter are found generally in the waters in the limestone formations and in the Triassic sandstones and shales. The smaller quantities are found generally in the waters of the Cambrian quartzites and sandstones, which are among the ground waters of lowest mineral content that are found anywhere in the United States. The waters from the pre-Cambrian formations of gneiss and schist rank next in mineral content to the Cambrian quartzites and sandstones, and many of the waters from the igneous rocks and from the Martinsburg shale are also very low in mineral matter.

With very few exceptions the waters from this area that were analyzed do not contain enough mineral matter of any sort to be unsatisfactory for drinking or cooking purposes, but some of the waters are moderately hard and some contain objectionable amounts of dissolved iron.

Hardness is produced chiefly by the calcium and magnesium that are dissolved in the water, and the hardness as given in the tables was calculated from the quantities of these constituents in the different waters. Hard waters are unsatisfactory for washing because they consume large amounts of soap and react with the soap to form curds instead of lather. In the waters of this area the hardness is chiefly bicarbonate hardness, which is largely removed when the water is heated. The calcium, magnesium, and silica are the principal constituents that produce scale in steam boilers. Hence, the hard waters are unsatisfactory for boiler use unless they are first treated to remove these constituents. The scale-forming constituents in the waters of this area can in large part be removed by pre-heating, but other treatment is necessary for complete softening and removal of scale-forming constituents.

As the dissolved solids in the waters of each of the principal groups of formations consist largely of the constituents that cause hardness, the waters of the several groups rank about the same in hardness as in total solids. The waters in the limestones are practically all hard. The waters in the Triassic sandstones and shales average nearly as high in hardness as the limestones and they include some of the hardest waters in the area. On the other hand, some of the Triassic waters, especially some of the waters in the Stockton formation, are relatively low in hardness. The waters in the serpentine are also hard owing to their large content of magnesium, but in the other igneous rocks and the gneisses and schists are for the most part relatively soft. The softest waters, however, are in the Cambrian quartzites and sandstones.

The 41 limestone waters that were analyzed have an average hardness of 239 parts per million and about half of them have a hardness between 200 and 300 parts. The 6 waters from the Cambrian quartzites and sandstones range in hardness from only 7.8 parts to only 27 parts. The 33 Triassic waters have an average hardness of 196 parts but they range from very soft water to the hardest water analyzed. The 6 waters from the serpentine have an average hardness of 185 parts, the 4 from gabbro 47 parts, the 29 from gneiss or schist 54 parts, and the 9 from the Martinsburg shale 89 parts. Many of the fertile and well populated valley areas are underlain by limestone that produces hard water but are bordered by rugged ridges of quartzite that yields soft water. In these situations supplies of soft water can be developed in the mountains from springs or wells and can be led in pipe-lines to the settlements in the valleys.

Even comparatively small quantities of iron dissolved in water are likely to be objectionable, because the iron is readily precipitated and may stain plumbing fixtures and clothing washed in the water. Some iron-bearing waters have a distinctive taste, which, however, is not objectionable to those who habitually use them for drinking purposes. Water containing more than 1 part per million of iron is generally objectionable and water containing several parts is very objectionable. On the other hand, water containing much less than 1 part per million is not seriously objectionable and water containing less than one-tenth of 1 part may be regarded as practically free of iron.

A grouping of the waters of the different formations as to iron content is given on page 77. Of the 142 waters that were sampled in this area, 18 were shown by the analyses to have an iron content of 1 part per million or more. Of these 18 waters 8 were obtained from gneiss or schist, 3 from Triassic rocks, 2 from serpentine, 2 from the Harpers formation, 1 from other igneous rock, 1 from limestone and 1 from Martinsburg shale. Among the seven principal groups of rocks given in the tables, the limestones are lowest in iron content, the Cambrian quartzites and sandstones rank second, and the Triassic sandstones and shales rank third, whereas the gneisses and schists are highest. Of the 41 limestone waters 22 contain less than one-tenth of 1 part and 35 contain less than two-tenths of 1 part per million of iron. Of the 6 quartzite waters, one contains .78 part and another .53 part but the other four samples were very low in iron. The average iron content of the 33 Triassic waters was brought up by two samples, which contained respectively 4.9 and 17 parts. Of the

remaining 31 waters only one contains more than 1 part per million whereas 16 contain less than one-tenth of 1 part. The 8 samples from the Stockton formation showed an average iron content of only about .07 part per million, the range being from .05 to .10 part.

As has already been pointed out, the mineral matter dissolved in the ground waters of this area consists largely of calcium and magnesium in equilibrium with the bicarbonate radicle. Only a few exceptional waters contain large amounts of sodium or of sulphate or chloride. Of the 142 waters analyzed only 6 contain more than 100 parts per million of the chloride radicle whereas 88 contain less than 10 parts. The waters from the Cambrian quartzites and sandstones, which are extensively used because of their softness, range in chloride, in the 6 samples analyzed, from only .5 to 10 parts per million and have an average chloride content of only 2.6 parts.

The waters of each group have a wide variation in their content of the nitrate radicle, and range from practically nothing or very small amounts up to rather large amounts of this constituent. On the whole the nitrate content is high as compared with that of most ground waters in other parts of the United States. Moreover, its origin is not apparent. The rocks of the area, especially the pre-Cambrian metamorphic and igneous rocks, were never rich in organic matter from which the nitrate could be derived or else presumably lost most of their organic matter a very long time ago. On the other hand, the samples were nearly all derived from drilled wells or springs in most of which extensive surface pollution from human or other animal excreta would not be expected. The area is, however, one of luxuriant vegetation, and it does not seem improbable that considerable nitrate derived from decaying vegetable matter is dissolved by the soil water and is eventually carried down to the water table.

Range in dissolved mineral matter and average composition of waters analyzed from the principal groups of rock formations in southeastern Pennsylvania.

Range	Number of analyses		Total dissolved solids	Silica SiO_2	Iron Fe	Calcium Ca	Magnesium Mg	Sodium and potassium Na+K	Bicarbonate HCO_3	Sulphate SO_4	Chloride Cl	Nitrate NO_3	Hardness
			Parts per million										
Pre-Cambrian gneiss and schist	29	Lowest	19	4.1	.03	1.7	1.4	2.2	7.3	2.1	1.3	trace	9
		Highest	406	57	8.7	56	24	44	105	70	121	175	224
Igneous rocks—pre-Cambrian and Triassic	16	Lowest	66	9.4	.04	2.1	4.2	1.7	15	3.0	2.4	.08	31
		Highest	851	40	5.4	99	76	119	329	59	342	167	391
Cambrian quartzite and sandstone	6	Lowest	17	4.1	.03	1.5	.7	.9	5.4	1.6	.5	0	7.8
		Highest	64	9.1	.78	4.6	3.9	7.6	24	5.1	10	25	27
Limestone, dolomite and marble (pre-Cambrian, Cambrian, and Ordovician)	41	Lowest	75	7.9	.02	5.6	2.4	1.1	41	3.4	1.0	0	24
		Highest	889	33	1.9	118	52	76	388	116	127	216	508
Martinsburg shale	9	Lowest	35	8.4	.03	2.5	2.2	1.9	15	3.6	1.0	.27	20
		Highest	266	22	1.4	39	17	31	152	55	35	102	115
Triassic sandstone and shale	33	Lowest	44	6.2	.01	3.4	1.4	2.1	16	3.0	.9	trace	14
		Highest	1,106	33	17	209	49	183	283	581	540	84	557
Average													
Pre-Cambrian gneiss and schist	29		112	17	1.2	12	5.6	11	28	10	16	20	54
Igneous rock	16		219	25	.65	24	18	16	83	18	37	34	133
Cambrian quartzite and sandstone	6		30	6.0	.26	2.4	1.6	2.8	10	3.6	2.6	4.6	14
Limestone, dolomite, and marble	41		304	15	.18	61	20	12	222	33	20	21	239
Martinsburg shale	9		143	15	.30	21	9.1	11	74	24	11	14	89
Triassic sandstone and shale	33		299	21	.83	51	16	21	142	64	32	13	196

Summary of total dissolved solids in waters analyzed from the principal groups of rock formations in southeastern Pennsylvania.

Group of rock formations	Number of analyses	Waters with specified limits of total dissolved solids, expressed in percentage of total number of waters analyzed				
		Not more than 50 parts per million	51 to 100 parts per million	101 to 200 parts per million	201 to 500 parts per million	More than 500 parts per million
		Per cent	Per cent	Per cent	Per cent	Per cent
Pre-Cambrian gneiss and schist	29	28	41	14	17	0
Igneous rocks—pre-Cambrian and Triassic	16	0	37	19	38	6
Cambrian quartzite and sandstone	6	83	17	0	0	0
Limestone, dolomite and marble—pre-Cambrian, Cambrian and Ordovician	41	0	2	17	70	11
Martinsburg shale	9	22	11	45	22	0
Triassic sandstone and shale	33	3	18	18	54	12

Summary of hardness of waters analyzed from the principal groups of rock formations in southeastern Pennsylvania.

Group of rock formations	Number of analyses	Waters with specified limits of hardness, expressed in percentage of total number of waters analyzed				
		Not more than 25 parts per million	26 to 50 parts per million	51 to 100 parts per million	101 to 250 parts per million	More than 250 parts per million
		Per cent	Per cent	Per cent	Per cent	Per cent
Pre-Cambrian gneiss and schist	29	48	18	17	17	0
Igneous rocks—pre-Cambrian and Triassic	16	0	38	12	38	12
Cambrian quartzite and sandstone	6	83	17	0	0	0
Limestone, dolomite and marble, pre-Cambrian, Cambrian and Ordovician	41	2	0	2	64	32
Martinsburg shale	9	22	11	11	43	0
Triassic sandstone and shale	33	3	15	12	37	33

Summary of content of dissolved iron in waters analyzed from the principal groups of rock formations in southeastern Pennsylvania.

Group of rock formations	Number of analyses	Waters with specified limits of dissolved iron, expressed in percentage of total number of waters analyzed		
		Not more than .10 part per million	.11 to 1.0 part per million	More than 1.0 part per million
		Per cent	Per cent	Per cent
Pre-Cambrian gneiss and schist	29	31	41	28
Igneous rocks	16	12	75	13
Cambrian quartzite and sandstone	6	50	50	0
Limestone, etc.	41	56	42	2
Martinsburg shale	9	33	56	11
Triassic	33	52	39	9

UTILIZATION OF GROUND WATER

The uses of water are very numerous, but for the purpose of this report the water supplies of the area may be divided rather arbitrarily into (1) private supplies for domestic use, (2) supplies for live-stock, (3) supplies for industrial uses, including cooling, (4) railroad supplies, and (5) supplies for systems of public waterworks.

DOMESTIC SUPPLIES

The use of springs and shallow dug wells dates back into antiquity, and around such sources of water supply have grown up many important centers of civilization. In southeastern Pennsylvania the Indians and the first white men depended upon springs and streams for their water supplies. At first farm houses were usually built near springs but as the area was settled up localities where springs are not numerous were occupied and it became necessary to dig wells. Until about 1875 ground-water supplies were obtained either from springs or from dug wells, but about that time the first drilled wells were put down. Dug wells have gradually fallen into disfavor because they are frequently subject to pollution and many of them fail in dry weather. At present nearly all new wells are drilled.

The domestic use of water may be said to include drinking, cooking, cleaning, and disposal of sewage. For drinking and cooking, water is required that is not only wholesome but is also free from any offensive taste or smell. Ground water from springs or wells may be dangerously polluted with organic matter, and care should, of course, be taken to avoid such polluted water or to remove the sources of pollution. In this area ground water rarely contains enough dissolved mineral matter to make it objectionable for drinking or cooking. In a few localities water obtained from serpentine is so thoroughly charged with magnesium sulphate that it imparts an undesirable taste. When the water is cool it may be difficult to detect the unpleasant taste, but when warm the unpleasant taste becomes more pronounced. In some places the ground water contains objectionable amounts of iron in solution. This is particularly true of those waters from which iron is precipitated in the form of one of the hydrated oxides upon exposure to the atmosphere. With these exceptions few if any of the ground waters in this area are sufficiently highly mineralized to interfere with their use for cooking or drinking.

The water from the crystalline rocks and the Triassic formations is usually soft enough to be satisfactory for washing and bathing. However, waters from the Cockeysville marble and the serpentine are frequently very hard, and in a few localities hard water has been reported from the Wissahickon formation. The waters from the Cambrian and Ordovician limestones and from the Martinsburg shale are usually hard and many people in areas of those rocks use rain water for laundry and cleaning purposes.

The objection to hard water for these purposes is its action on soap. With water low in hardness soap lathers freely, but with hard water it not only refuses to lather but forms insoluble curdy material. This material is the result of the chemical combination of the acid radicle of the soap with the calcium, magnesium and iron dissolved in the water. This chemical process not only consumes a large amount

of soap but on account of the scum and curds that are produced it makes washing unpleasant and ineffective.

In a region such as southeastern Pennsylvania, where the rainfall is heavy and frequent, rain water is easily collected. The most primitive method of doing this is to have a barrel under a rainspout to catch the water from the roof of the dwelling or other buildings. This method is inexpensive but is far from satisfactory for a number of reasons. Few barrels hold more than 50 gallons, which is a relatively small quantity of water. In summer, if proper precautions are not taken to keep a screen cover on the barrel, it may become a breeding place for mosquitoes. In winter, due to cold weather, the water may freeze and can then be obtained only with difficulty. Consequently, a cistern built either under ground or in the building is of greater utility. A cistern has greater storage capacity, is more easily protected from mosquitoes, and rarely freezes. A storage tank installed in the upper story or attic of a house has the advantage that it will supply water under pressure without pumping, but if proper precautions are not taken it may be a source of danger due to its weight and to the possibility of leaks.

LIVE-STOCK SUPPLIES

In most parts of southeastern Pennsylvania, in the localities underlain by the Cambrian and Ordovician limestones, fields used to pasture live stock are so arranged that they include running streams, from which the stock can obtain adequate water. On many farms the barn is built close to a spring that furnishes water for the horses and cattle. On farms less favorably situated there is usually a well or two to furnish water for the animals that are not out grazing. In some localities, especially those underlain by gabbro, there may be difficulty in obtaining supplies of as much as 10 gallons a minute from wells. In these localities, as it is in the areas underlain by limestone, it may be necessary to install large cisterns.

Live stock has much greater tolerance than human beings for water high in dissolved solids. Apparently no difficulties are encountered with water too highly mineralized for stock use in any part of the area covered by this report. None of the waters are reported as unfit for stock.

INDUSTRIAL SUPPLIES

Industrial use of ground water is of great importance in a highly developed area such as southeastern Pennsylvania. In earlier years municipalities and water companies that derived their water from streams usually supplied untreated water the turbidity of which varied from day to day. Consequently all industrial plants that required clear water were forced either to install filters or to develop water supplies from wells or springs, which with some exceptions in limestone areas, usually yield very clear water. In more recent years public supplies are usually filtered and consequently are low in turbidity, and they are usually also chlorinated to give them additional safety for human consumption. Many industrial concerns, however, still obtain their water supplies from wells in order to avoid the cost of the water from the public waterworks.

Ground water is probably in greater demand for cooling purposes in southeastern Pennsylvania than for any other industrial use. It is

particularly in demand at ice and refrigeration plants, commercial alcohol distilleries, and oil refineries. In all cooling work the great advantage of ground water is not only its relatively low temperature but also its uniform temperature throughout the year. The temperature of ground water in this area ranges from 47° to 56° F., but the temperature of water from any one well rarely varies more than 2° or 3° during the year. On the other hand, water from surface sources may vary during the year from 40° to 80° F., or through a still wider range. In summer ground water is, therefore, an almost ideal cooling agent.

Recent experiments have been conducted at West Chester and Kennett Square, which are the important centers of the mushroom industry, with use of ground water as a cooling agent. The art of mushroom growing has been highly developed in Chester County with the result that great quantities of mushrooms are raised each year for the markets of Philadelphia and New York. The mushrooms are grown in low sheds in specially prepared soil. As they will not thrive in high temperatures it is almost impossible to grow large marketable crops during the summer and early autumn. Attempts have been made to cool the mushroom sheds with water pumped from wells. One method is to drive a current of air by means of a fan through an elongated chamber into which the water is dropping in the form of a fine mist which cools the air. The cooled air is driven into the shed, and circulates until it is finally discharged. Another method that has been tried consists of equipping a shed with a series of 1-inch or 2-inch pipes through which is pumped water from wells. The air comes in contact with the pipes and consequently becomes cooled and settles down over the mushroom beds. This is new use for ground water as a cooling agent, and more experimental work is necessary before it can be listed as one of the regular uses of ground water. So far, results from these various efforts have not entirely fulfilled the expectations of the experimenters.

Another important use for ground water is for boilers. If large volumes of water are needed for boilers the cost of water obtained from public waterworks may be considerably higher than the cost of water pumped from private wells. Therefore, where water of suitable quality can be obtained in sufficient quantity from wells, many industrial concerns effect a considerable saving by pumping their own supplies. The water from the crystalline rocks is generally low in dissolved solids and low in hardness, but occasionally wells yield water that can only be used in boilers after it has been softened. The waters from the Cambrian and Ordovician limestones and from the Triassic rocks except the diabase are usually too hard for use without treatment. With the improvement of water softening devices, they have come into common use and have made available for boilers many waters which were formerly not satisfactory. Most of the waters obtained from the coastal plain surficial formations in Philadelphia are sufficiently low in dissolved mineral matter to be used in most boilers without treatment.

Ground waters vary in their iron content in an irregular manner with both location and depth, and the waters from wells in the same locality may differ radically in this respect. Many of the ground

waters in this area contain considerable iron, especially those from the crystalline rocks. A number of industries require water that is low in iron. Such industries should be located either where surface waters of low iron content are available, or else, by careful tests of selected wells, where ground water of low iron content is known to exist.

Laundries use large volumes of water, and soft water that is nearly free of iron is needed. The crystalline rocks in general yield water that is soft but may contain considerable iron, which must be removed in order to make the water acceptable for laundry use. Nevertheless, in many cases, a softener will more than save its cost by removing the relatively small amounts of calcium and magnesium that exist in the water. In some places it is difficult to obtain wells in the crystalline rocks that will yield water in amounts that are adequate for laundry use. In the areas that obtain their water from the Cambrian and Ordovician limestones and Triassic rocks laundries rarely have much difficulty in obtaining adequate supplies of water but the water is frequently hard. Practically all large laundries which obtain water from either of these groups of rocks use water softeners. Modern softeners are so efficient, require so little attention, and save so much soap that they are virtually essential for all laundries where hard waters are used.

RAILROAD SUPPLIES

Railroads have two chief uses for water—drinking and locomotive use. Drinking water on trains must fulfill certain requirements laid down by the Interstate Commerce Commission. It is usually obtained in the large terminal cities which have carefully treated supplies from surface sources. The requirements of the Interstate Commerce Commission concern health and sanitation and permit the use for drinking of any water that is bacterialogically safe. The only waters from this area that the railroad companies could properly condemn for drinking purposes on chemical grounds are some of the magnesium sulphate waters obtained from the serpentine.

The requirements for locomotive use are quite different. These requirements are that large supplies should be available and that the water should not foam and should form only a minimum amount of scale. The Pennsylvania Railroad Company found so much difficulty in developing local supplies that the Octoraro Water Company was formed, which impounded the water of Octoraro Creek and supplies practically all the requirements of the railroad in the area east of the Susquehanna from this source. At Oxford, however, the Pennsylvania Railroad Company has a drilled well which yields large volumes of water. The Reading Railway Company also obtains some water from wells in the crystalline rocks. In general, the quality of the water from the crystalline rocks is sufficiently good for locomotive use but the difficulty is to obtain supplies that are adequate in quantity. The tanks on the tenders of locomotives hold from 3,000 to 10,000 gallons, and where locomotives are numerous very large quantities of water must be available. Though the Triassic rocks and the Cambrian and Ordovician limestones generally yield larger supplies, their waters are frequently so hard and full of scale-forming materials that surface water is usually preferred in the belts underlain by these rocks.

MUNICIPAL SUPPLIES

No community can prosper and progress without a system of public waterworks, owned either privately or by the municipality. The advantages of a public water supply are so obvious that it is almost unnecessary to discuss them.

When a municipality decides to install a system of public waterworks a decision must be made whether a surface-water supply or a ground-water supply is the more feasible. There is no absolute rule for deciding this question, but, in general, a small town is best served with a ground-water supply, where such a supply can be developed, whereas for a large city a surface-water supply is generally more feasible. A surface-water supply, especially if it is obtained from a stream that becomes turbid in high stages, requires a rather complicated process of settlement, chemical treatment, filtration, and chlorination, which must be conducted under continuous technical supervision. If large quantities of water are treated the unit cost may be very low but for villages and small cities, with relatively small consumption of water, the unit cost will be much higher, and may become virtually prohibitive. Furthermore, the result of these high unit costs is likely to be that the treatment is not carried out effectively under adequate technical supervision, and hence that the water may be in a condition dangerous to health. The problem of obtaining water supplies in the three belts (see page 10) in this region are very different. On the other hand, if satisfactory wells are obtained and proper pumping machinery is installed, a ground-water supply requires but little supervision, is in less danger of pollution, and can be furnished at moderate cost.

The problems of obtaining ground-water supplies are very different in the three belts into which this area has been divided. In the crystalline rocks it is generally advisable to develop supplies for small communities from springs if practicable, and otherwise to drill one or more wells to moderate depths into the rocks. The crystalline rocks rarely yield large supplies to either wells or springs. Considerable difficulty may be experienced in developing supplies of even as much as 100 gallons a minute.

Where springs are available they should be cleaned out and inclosed in such a way as to prevent pollution, and possible sources of pollution on higher ground in the vicinity should be removed. The water should be conducted to a central collecting basin in pipes rather than to let it flow over its natural stream channel. This will not only reduce the danger of pollution but will also prevent evaporation losses which are highest in hot weather when the consumption is also greatest and when yield of the springs is usually the least. Not only should each spring be developed but all damp places which seep moisture. These places are frequently favorable sites for collecting galleries which may augment the yield of the springs. In developing groups of springs some of the small springs are frequently neglected, because they appear to yield so little water that they do not deserve attention. It should be remembered that a spring which flows only 1 gallon a minute will yield 1,440 gallons a day. In some places it may be possible to purchase several small groups of springs and to develop them and pipe them to a central point. In general springs in the crystalline rocks yield water of excellent quality, and most of the difficulties that

are encountered with them are due to the small volumes obtainable. In some places the springs occur at sufficient elevations above the town where the water is used that the water does not have to be pumped, but owing to the moderate relief of much of the Piedmont Province most villages are not so fortunately situated.

In the areas underlain by crystalline rocks attempts are frequently made to develop the entire supply for a system of waterworks from one well. Of course this is the most economical method where it is possible, because it reduces the investment and the cost of maintenance and operation. However, few wells in the crystalline rocks yield more than 25 gallons a minute, and many yield less than 10 gallons a minute. In any event it is desirable to have a duplicate well for use when repairs must be made. The best procedure in the areas of crystalline rock often is to purchase a farm near the top of the watershed, which can be protected from pollution, and then to drill wells as needed. In some cases where relatively large supplies were needed, those in charge decided to drill in the same hole until the required supplies were obtained. Consequently some wells have been drilled to depths of 1,000 feet or more without obtaining much water. If the money invested in one deep well had been used to drill two or more shallower wells situated 300 feet or more apart a larger volume of water would in most cases have been obtained. As suggested under the discussion of the water-bearing properties of the various kinds of crystalline rocks, it is inadvisable to drill much deeper than 300 feet below the surface, because, as a rule, water-bearing openings in the crystalline rocks become smaller and fewer below that depth. A few wells in the area obtain water at greater depths, but no data were obtained as to any wells that encountered large supplies of water at a depth of more than 500 feet. Consequently, it is regarded inadvisable to drill to a greater depth in localities underlain by crystalline rocks. In some places it may be necessary to drill from two to ten wells to obtain supplies adequate for a village of 1,000 inhabitants. If good pumps of the proper type and size are installed and electric power is available one man can take care of a large number of wells, and the cost of pumping need not be excessive. The use of a well farm, with the installation of additional wells as needed, would go far toward solving the water-supply problems of many of the towns in the belt of crystalline rocks.

Water obtained from the crystalline rocks is generally clear, and if proper precautions are taken to prevent or remove polluting agencies in the vicinity of the wells it is safe and wholesome. It is not necessary to filter the water, unless it is desired to remove the iron that is precipitated out of the water in some localities. If there is any danger of pollution the water should be chlorinated. In recent years, in some cases, it has been found necessary or advisable to chlorinate the water in order to make it safe for drinking. This is usually done with liquid chlorine injected into the water by an automatic device.

In the belt of the Cambrian and Ordovician limestones the problem of water supply is somewhat different. In the past most villages and towns in localities underlain by limestone obtained their supplies from some of the large springs that are to be found in the limestone valleys. Many of these springs yield volumes of water that greatly exceed the requirements of the communities using them. However, some large

towns and cities, such as Allentown, have been forced to augment the supplies obtained from springs.

The result of drilling in limestone is always uncertain. Some wells will yield large supplies but others will yield little or no water. In most localities underlain by limestone deep wells are not successful, but in the vicinity of Bethlehem several successful deep wells have been drilled. In general, in this area, not much water is found in limestone below the depth of 300 feet.

Water obtained from springs and wells in the limestone is frequently polluted owing to close connection between sink holes and underground channels. Many surface streams disappear in sink holes and reappear as large springs. Surface streams in densely populated regions are all polluted, and consequently many springs and wells that are fed by underground streams in limestone are polluted. The difficulty is further aggravated by the common practice of waste disposal in sink holes, whereby pollution finds its way directly into the ground water. Therefore, it is advisable to chlorinate all public water supplies obtained from limestone.

All water from the limestone is hard although the amount of hardness varies from well to well, and from spring to spring. The water is usually so hard that it must be treated by some softening process before it can be satisfactorily used for boiler feed or for some of the other industrial processes. In towns supplied by unsoftened limestone water the householders usually avoid the use of this hard water for laundry purposes by installing cisterns in which they store rain water.

The problem of supplying the communities on the Triassic red beds is somewhat simpler except in those towns and villages which are on the Lockatong formation or its equivalent. The Lockatong formation, which consists chiefly of dense, dark shales and other impervious sediments, is a poor water horizon; but the other formations of the Triassic system are fairly good water horizons. The Triassic rocks usually yield considerable volumes of water, and wells 100 to 500 feet deep yielding from 50 to 200 gallons a minute are common. In some places a single well will furnish an adequate supply for a small community; but for most places, two or more wells are required. Even when one well will furnish enough water it is advisable to have an additional well for emergencies. If large yields are required, wells of at least 8 or 10 inches in diameter should be drilled.

The estimates of the volume of water needed to supply a town vary greatly when preparations are being made to install a water supply, particularly when the water system is to be paid for by public funds. A number of factors must be considered in estimating the requirements of the particular community to be served. The future as well as the present must be considered, particularly with respect to the source of water, the type of community, the kind and amount of growth that may be normally expected as well as the amount of money available.

The towns and cities in the United States range in their daily requirements from a minimum of less than 25 gallons to a maximum well over 200 gallons per capita. In a residential town without industries, with new and properly constructed waterworks, and with meters installed on all services, the amount used may be less than 25 gallons. On the other hand, in a city with numerous industries or in any com-

munity with an old, leaky system of waterworks and charging flat rates the per capita consumption may be very high. In recent years many communities have curbed waste by careful inspections of mains and services to discover and prevent losses, and have thereby made it unnecessary to provide enlarged supplies that otherwise would have been required.

RECOVERY OF GROUND WATER

SPRINGS

Springs, wells, and collecting galleries are the chief means of making ground water available for human use. Springs have been used by man since time immemorial. In ancient times many springs were so highly regarded that temples and shrines were erected beside them, and villages and towns grew up around them.

Springs, in the strict sense of the word, are the natural openings from which ground water is discharged. However, man learned long ago that by digging in damp places he could obtain water and produce the equivalent of a natural spring. He also long ago learned that the discharge of many springs could be increased by carefully cleaning out the springs and sometimes by excavating the soil and rock in the vicinity of the springs. At present great ingenuity is frequently exercised in developing springs.

Many prosperous farms center about springs. Some of these springs have been improved by erecting concrete curbings, masonry walls, basins, and spring houses, and in some cases by the installation of pumping devices. However, it is surprising that there are still so many springs in use from which all water must be carried in containers to the house. At a few places the water from springs is lifted through pipe lines to the dwellings on higher land by means of hand pumps. At other places windmills have been installed which pump the water to elevated tanks from which it is distributed by gravity. Windmills are not entirely satisfactory in this area because the winds are so variable in intensity. Periods of calm which last several days are frequent, especially during the summer months when consumption of water is greatest. Severe storms are liable to damage the windmills, as is shown by the number of damaged and abandoned mills seen through the country. In recent years the windmill has lost some of its popularity and has been more or less superseded by the small internal combustion engine. These engines have been highly perfected in recent years, and most new pumping installations are equipped with engines that use either gasoline or kerosene as fuel. These engines are used to pump water either to an elevated tank or into a pressure system. Hydraulic rams have not been widely used in this area. However, a ram that will operate on a relatively low head and lift a fraction of the spring flow to higher levels is a most attractive device wherever relatively large springs are available, because the initial cost and the maintenance cost are low, and the ram is driven by water power that would otherwise go to waste. Many of the springs in use yield such small amounts of water that they could not operate a ram, but springs that yield more than 5 gallons a minute and have a fall of several feet would operate a small ram very nicely. A number of springs now used only to supply cattle in pastures could be developed with hydraulic rams

without impairing the water supply for the cattle because a ram lifts only a small part of the water that passes through it.

WELLS

There are a number of types of wells such as dug wells, drilled wells, bored wells, and driven wells. Dug and drilled wells are practically the only types in use in this area except in a few places in the localities underlain by the Coastal Plain sediments, where driven and bored wells are in use.

DUG WELLS

Long ago man learned that holes dug in the ground frequently contained water which was obtained directly from the rainfall. He also learned that holes dug sufficiently deep would in many places strike "living water." In regions where springs were not numerous trading places and villages often grew around wells. Dug wells have been put down at the cost of enormous amounts of labor. In southeastern Pennsylvania the first settlers generally located their houses near springs, which are largely confined to valleys. Later the uplands were settled and it was necessary to dig wells. Hence literally thousands of wells have been dug in this area ranging in depth from 10 to 100 feet or more. Some of these wells yield very little water; others yield large supplies. The wells were dug to water and deepened a few feet to form a storage basin. In dry years many of these wells failed and were deepened until the water table was again encountered. This process was repeated until many of these old dug wells are unfailing or go dry only in exceptionally dry years. Many of these wells are so old and have been in use so long that little information is available concerning them. They have given so little trouble that the present owners or users have given very little attention to them and frequently do not know the depth of the well or the number of feet of water standing in the well in normal years.

In recent years a dug well is generally sunk by a well digger and one or two helpers. The site is selected, the hole is excavated to a depth from which it is no longer possible to cast the dirt, and then a framework is erected with a windlass to which a bucket is attached by means of a rope. The bucket is lowered into the hole, filled with earth, hoisted to the top and emptied. This operation is continued until the hole penetrates the water table. In some places solid rock is encountered, either before or after the water table is reached, and blasting is necessary. Rock is usually removed until water is encountered in joint planes or other openings. However, digging through solid rock is difficult work, and most dug wells do not penetrate far into it.

Dug wells are finished by cribbing with wood, brick, stone, or drain pipe, which prevents the sides from caving. Wood is the cheapest and most easily installed material but in the long run is the least satisfactory because of its short life and the necessity of frequent renewals. Wells that are not properly cased are usually liable to damage by caving and are easily polluted.

Dug wells in the most primitive state are left open, and the water is lifted from them by means of a bucket on the end of a rope, or the bucket may be attached to a well sweep. Most dug wells are, however, now fitted with pumps of some description, either hand, wind, or en-

gine driven. Engines are by far the most popular at present. Many wells are being equipped with pressure system.

Many people fail to take proper care of their dug wells. The curbings and covers on many dug wells are not watertight nor proof against the entrance of small animals. Many of them are covered with boards which have spaces between them that permit both rain-water and well water that is spilt to run into the well and to carry down filth and dirt. This type of well should be equipped with a watertight cover, preferably of concrete. It should also have a watertight curb at the top and preferably to the water level or the horizon at which the water enters the well. The cover should be at least a foot above the ground surface and the ground should be banked so as to slope away from the well in all directions. A pit privy should not be used where the water supply is obtained from a dug well or it should be situated on lower land, preferably a few hundred feet from the well. If the privy is on lower land

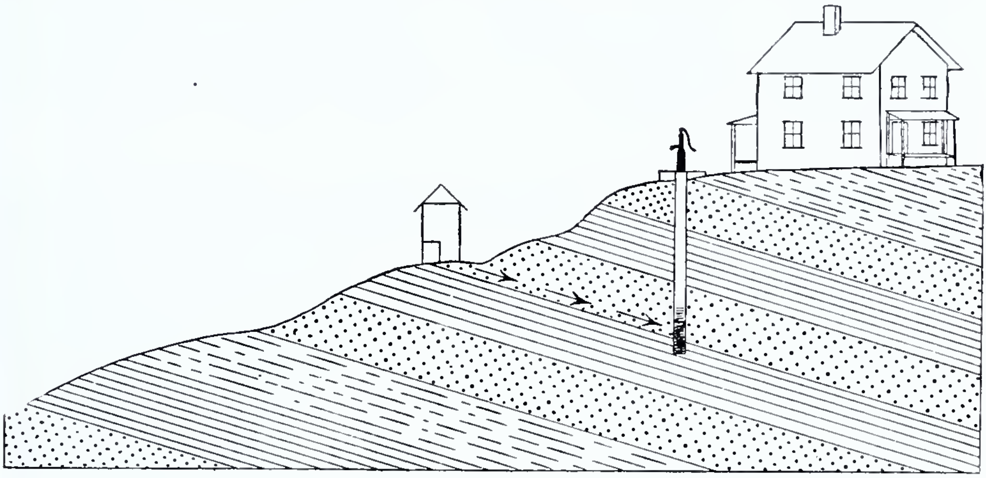


Fig. 8. Diagram showing well polution

and the rock strata or joints pitch from it toward the well, pollution may result unless the distance is adequate so that there is no connection between the two. One advantage of a dug well is the large volume of water that it may hold in storage. A dug well that is 4 feet in diameter and has a depth of water of 10 feet contains more than 900 gallons. Consequently, although this type of well has its disadvantages it has the great advantage of holding for immediate use a large volume of water.

DRILLED WELLS

In recent years drilled wells have largely supplanted the dug wells. They have numerous advantages and relatively few disadvantages. They are drilled by "churn drills," or portable percussion rigs, which consist essentially of a heavy chisel-like drill at the end of tools suspended by a rope of hemp or steel from a beam that rises and falls. The source of power may be either a steam or gasoline engine. The drill drops upon the rock, crushing it or cutting off fragments. When the bottom of the hole becomes clogged with cuttings and the drill no longer strikes the rock effectively, it is withdrawn and the cuttings are removed by means of a bailer. This process is continued until a suffi-

cient supply of water is encountered or, in rare cases, the hole abandoned. Drilled wells may be put down in consolidated or unconsolidated materials. Many drilled wells pass through a layer of unconsolidated material into solid rock. Except in the wells that start in solid rock, it is usually necessary to insert a lining of steel pipe or casing. The purpose of this casing is to prevent the loss of the well by caving and to prevent the entrance of surface pollution. The amount of casing required depends on the character of the material through which the well is drilled.

Most wells in any of the three belts end in relatively solid rock and are finished open; that is, the casing ends some distance above the bottom of the hole. In some of the wells ending in limestone difficulty has been encountered on account of the influx of mud from solution channels, the mud being carried in suspension by the moving water. This difficulty can often be overcome by pouring spongy blast furnace slag into the well. The fine openings in the slag catch and retain the mud, permitting clear water to be pumped from the well. Wells ending in the Coastal Plain sediments, chiefly in the lower part of Philadelphia, are commonly finished with slotted or perforated pipe or with manufactured screens of different types. Not much trouble with silt entering these wells was reported.

The yield of drilled wells ranges from only about 1 gallon a minute to several hundred gallons a minute. In general the weakest wells are those which obtain their water from gabbro and the largest producers those which obtain their water from the Cretaceous beds of sand or gravel in the lower part of Philadelphia. The wells in the crystalline rocks yield small supplies. Indeed, many of them yield less than 5 gallons a minute, and a number of them yield only 1 or 2 gallons a minute. A well yielding less than 5 gallons a minute is considered by many people as a failure, but in fact a well of considerable smaller yield, if properly managed, may be a satisfactory source of supply for domestic and farm use. A well in Lenni Mills, Delaware County, that yields only 1.5 gallons a minute is used to supply a number of families. Where it is desired to install pressure systems wells yielding 2 gallons a minute or even less are adequate, particularly if the wells are deepened to afford considerable storage, even though the deeper drilling may not increase the yield. A 6-inch well with 100 feet of water in it contains about 145 gallons, while an 8-inch well with the same depth of water contains about 250 gallons. With a pump having a capacity of only 2 gallons a minute, a well yielding only 1 gallon a minute is sufficient to supply a small pressure system with a storage tank, though it would not be adequate to operate a direct type without the tank.

COLLECTING GALLERIES

A collecting gallery is a tunnel or drift that is run below the ground water level and hence receives water by percolation from the saturated rocks. In some places such tunnels driven into hillsides from which springs issue may greatly augment the supply. In southeastern Pennsylvania very few such tunnels have been dug, but it is probable that in certain localities where springs are numerous large volumes of water might be produced by their use. Collecting galleries are in use at Reading and Mohnton in Berks County.

PRESSURE SYSTEMS

Different methods have been used to furnish isolated homes with water under pressure. The earliest method to be used in this area consisted of a tank installed in a hillside near the house, on a tower erected for the purpose, or on the top floor of the dwelling house. In many places hills were not available and it was necessary to erect expensive towers or to put the tank in the house where it might cause damage by leaking. The method of lifting the water into the tank has also been somewhat of a problem. Hydraulic rams are inexpensive but can not be operated except under certain favorable conditions, windmills are uncertain on account of the variability of the winds, and gasoline engines, though more dependable, are relatively expensive to operate and require considerable attention.

In recent years there has been very extensive suburban development in parts of this area and it has not generally been possible to connect the suburban residences with the city water systems. Moveover, there has been a demand for greater comfort in the farm homes. In response to these demands modern pressure systems have been developed. One type has a tank; the other has no tank but the pump is connected directly to the supply lines.

The tank type is the older development. It has the advantage of having a reserve supply and can therefore be used with a well that yields only from one gallon to a few gallons a minute. The pump can be driven by a gasoline engine but an electric motor is more dependable and requires less attention. A drop in pressure automatically starts the engine and pump, which operate until a determined pressure is obtained, when they are automatically stopped.

The type without the tank is the newer. In general it requires a well with a larger yield and also a larger pump and a larger engine or motor. In a system of this type the opening of a tap causes the pump to start, and closing it stops the pump. The elimination of the tank makes the device more compact and removes the chances of damage by leakage.

The source of power for the pumps in either type of pressure system is usually an electric motor with control-station service or a gasoline engine. The service lines of the electric power companies are rapidly being extended, and many isolated houses are now supplied with electricity. Where electric current is not available gasoline engines with storage batteries are an excellent substitute for electric motors.

The desirability of having water under pressure is obvious, especially to anyone who has pumped and carried water. There is probably no modern convenience which gives greater returns in comfort than the pressure system for small houses.

GROUND WATER DESCRIBED BY COUNTIES

ADAMS COUNTY

GENERAL CONDITIONS

Adams County is bounded on the south by the Mason and Dixon Line, which separates Pennsylvania from Maryland, and on the remaining sides by Franklin, Cumberland, and York counties. The area of this county is 528 square miles, and the population according to the United States Census of 1930 is 37,128, or 70.3 inhabitants per square mile. This is about one-third the average density for the entire State, which is 214.8. The rural population is 87.2 per cent of the total while the number of rural inhabitants per square mile is 60 or somewhat less than the number for the State, which is 66.9 per square mile. The population is distinctly rural and except Gettysburg, the county seat, which has a surface water supply, is dependent on ground-water supplies. The population of Gettysburg is 5584. The same census reports 3335 farms in the county. Cisterns for storing rain water are not extensively used.

The county is a prosperous agricultural area with some quarrying, particularly crushed stone for various purposes. Formerly, iron mining was active but at present the mines are idle. While a number of the towns have one or more manufacturing plants, none of them are strictly industrial towns. Gettysburg, the scene of the most famous conflict of the Civil War, is a tourist center which annually entertains thousands of visitors. Much of the battlefield is now Government property, with many miles of improved roads and many monuments erected to the men and military units engaged in the conflict.

GEOLOGY OF ADAMS COUNTY

The following geologic columns are inserted to serve as guide to the rocks exposed in the county and to assist in the interpretation of ground water conditions:

Generalized section of rocks in Adams County southeast of South Mountain.[1]

System		Formation names	Thickness in feet	Character of rocks	Water-bearing properties
TRIASSIC	UPPER TRIASSIC (Newark Group)	Gettysburg shale with fanglomerate lentils at top and Heidlersburg member in middle	16,000	Soft red shale and sandstones: middle 500 feet contains numerous gray to white harder sandstones. Fanglomerate lentils occur at top of the formation.	Wells less than 100 feet deep usually yield adequate domestic supplies. At Gettysburg large supplies have been developed between 200 and 400 feet.
		New Oxford formation	7,000	Red shale and sandstone, harder micaceous sandstone, arkose and conglomerate. The coarser sediments are more abundant in the lower half of the formation.	Wells usually obtain small supplies at a depth of less than 150 feet. It should be possible to develop larger supplies from the lower part of the formation.
		Unconformity			
ORDOVICIAN	LOWER ORDOVICIAN	Conestoga limestone	1,000±	Impure blue argillaceous limestone.	The limestones and dolomites contain solution channels which are generally filled with water. Wells which encounter these channels yield large supplies of water. Those in solid limestone will yield much smaller supplies.
		Unconformity			
CAMBRIAN	LOWER CAMBRIAN	Ledger dolomite	2,000±	Pure coarse gray dolomite with pure blue and white limestone marble.	
		Kinzers formation	50±	Dark argillaceous shale	
		Vintage dolomite	500±	Dark dolomite	
		Antietam sandstone	500±	Granular sandstone	Should yield large supplies of water low in total dissolved solids.
		Harpers phyllite	1,000±	Gray sandy schist	Should yield small supplies of fairly good water.
		Chickies quartzite with Hellam conglomerate member	800±	White vitreous quartzite; hard pebbly quartzite and conglomerate of glassy quartz at base.	Few wells have penetrated this formation which should yield moderate supplies of water low in total dissolved solids.
ALGONKIAN		Metabasalt (greenstone)	500±	Massive greenstone	Very few wells have been drilled in this material.

[1] Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio, (No. 225), 1929.

Generalized section of rocks for South Mountain area.

System	Series	Formation names	Thickness in feet	Character of rock	Water-bearing properties
ORDOVICIAN		Beekmantown(?) limestone	300±	Blue limestone.	Wells obtain large supplies from water solution channels.
		—Intervening formations concealed—			
CAMBRIAN	Lower and Middle Cambrian	Waynesboro formation	1,000±	Mottled sandstone and purple sandy shale at top, blue limestone and dolomite in the middle, and siliceous gray limestone and sandstone at base.	A fairly favorable horizon for small supplies. The sandstones may produce.
		Tomstown dolomite	1,000±	Coarse gray dolomite, blue limestone and some shale and schist.	Wells encountering water-bearing solution channels should yield large volumes of water.
		Antietam sandstone	800	Coarse quartzose sandstone.	Should yield large supplies of excellent water.
		Harpers schist with Montalto quartzite member	3000	Dark sandy slate or schist and white quartzite.	The formation should yield small supplies. The water from the quartzite should be low in total dissolved solids.
		Weverton sandstone	750	Gray and purplish feldspathic sandstone.	Should be a fairly good water-bearing horizon.
		Loudoun formation	550	Soft purplish arkosic conglomerate and fine sericite.	Water is found in bedding and cleavage planes.
		—Unconformity—			
ALGONKIAN		Metabasalt	1,000±	Massive to schistose greenstone.	Few wells have been drilled in these altered lavas. They are not promising ground-water horizons.
		Aporhyolite	1,000±	Bluish gray in pink and purplish felsite and sericite schist; tuff and breccia at top.	

[1] Stose, G. W. and Bascom, F., loc. cit.

The larger part of the county is a rolling lowland underlain by the relatively nonresistant shales and sandstones, predominantly of red color, broken here and there by hills formed by diabase dikes and sills. The western part of the county includes a part of the South Mountain which rises to an elevation of 1,800 to 2,200 feet above sea level or 1,300 to 1,600 feet above the lowlands. On the eastern edge of the county a part of the Pigeon Hills is included. These hills rise only a few hundred feet above the lowland.

The oldest rocks exposed in Adams County are the pre-Cambrian volcanic rocks in the South Mountain and in the Pigeon Hills. The basement rocks on which these lavas were poured out have not been exposed. The rocks were originally rhyolite and basalt which have been metamorphosed but still retain recognizable traces of their original character. The altered rhyolite is called aporhyolite and the altered basalt, metabasalt or more commonly greenstone. Aporhyolite includes not only devitrified rhyolites, but less altered material as well as sericite schists which are rhyolites so metamorphosed by pressure that a slaty cleavage has developed. The devitrified rhyolite is usually red or purplish red but tints of blue and gray are frequent. The rock is usually compact, but in places is amygdaloidal. Flow structure lines are prominent. The lithoidal phase ranges in color from deep red to purple and blue. It is compact and contains conspicuous light-colored feldspar crystals. Photographs of this material are shown by Stose[1] and Bascom[2]. The schistose rhyolite and sericite schist, the extreme metamorphic phase, have been mistaken for roofing slates by a number of people who have tried to develop them but without much success. This schist is usually very highly crinkled. Its colors range from purple to blue gray. The metabasalt, or greenstone, includes basalts in different stages of alteration. The least altered stage of the greenstone is a dark compact rock speckled with dark green chlorite, light green epidote or white quartz. Usually it is a compact chlorite schist that breaks into thin slabs. In places it is intensely crushed, sheared and veined with chlorite, epidote, and asbestos. Large quantities of the greenstone have been crushed for granules to be used in making roofing materials.

The water-bearing properties of these rocks are quite similar except that larger supplies should be obtained from the schistose and slaty phases because they have larger spaces for the accumulation and circulation of ground water. These rocks will yield small supplies to wells drilled 250 or 300 feet deep, but large supplies will in general be unobtainable.

The pre-Cambrian rocks are overlain unconformably by the Cambrian formations. The oldest Cambrian formation outcropping in this area is the Loudoun formation which is mapped with the Weverton sandstone on Plate I. The formation is at the surface in rough and thinly inhabited areas in South Mountain; and is of little importance as a source of ground water. The Weverton sandstone, which caps the higher portions of South Mountain, such as Jacks and Piney Mountains and Green Ridge, consists of beds of gray to purplish arkose, now largely altered to slate, with overlying beds of resistant mountain-

[1] Stose, G. W., Mineral resources of Adams County, Pennsylvania; Bull. C-1, Topographic and Geologic Survey of Pennsylvania, Harrisburg, 1925.

[2] Stose, G. W., and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio, (No. 225), illustration 1, 1929.

making sandstone and conglomerate composed of grains and pebbles of quartz and feldspar. The number of wells drilled in the quartzite is not large and data concerning them were not available. This formation should yield small supplies of excellent water to drilled wells not exceeding 250 feet in depth. The rock is dense but joint and bedding planes afford storage space for ground water.

The Weverton sandstone is overlain by the Harpers phyllite which consists almost entirely of greenish gray sericite and mica schist. The Montalto quartzite of the Harpers, so prominent on the western flank of South Mountain is apparently absent in the southwestern part of the county, but it is so well developed in the vicinity of Dillsburg, where the Lower Cambrian arenaceous beds dip beneath the Cambrian and Ordovician limestones that the schist is almost entirely replaced by quartzite. The entire interval between the Weverton and Antietam sandstones of this part of the area is made up of quartzite and sandstone. The areal extent of the Harpers phyllite is not great and is confined to the mountain area where the population is sparse and the occasional springs adequately supply all needs. Much of the area is in the State Forest Reserve. Drilled wells should yield small supplies.

The Harpers phyllite is overlain by the Antietam sandstone, a pure coarse-grained quartzose sandstone. The lower part of this sandstone is very dense, but the upper part is less so and weathers to a loose sand. This formation should yield small supplies of excellent water. However, like the Weverton sandstone and Harpers phyllite schist, it outcrops in a little inhabited region where small springs supply present needs.

In the western part of the county a few areas of uneroded Paleozoic limestones remain. The largest of these areas is along the eastern front of South Mountain in the vicinity of Virginia Mills, and another much larger area is exposed in the eastern part of the county in the vicinity of McSherrytown. The central lowland is undoubtedly underlain by limestone under the cover of Triassic beds, but the thickness of this cover is unknown. The limestone in the extreme northwestern corner of the county is the Beekmantown limestone, but the remaining areas are more like the succession of beds in the York-Lancaster region than that in the Cumberland Valley.

In the vicinity of Virginia Mills, the Beekmantown limestone consists chiefly of blue limestone. Few wells have been drilled in the area but such wells should be successful at depths of less than 250 feet. This limestone is dense and a poor water-bearing horizon except where it contains solution channels. Wells which miss these channels will be dry or yield small supplies.

In the area around McSherrytown the Vintage dolomite, the Kinzers formation, the Ledger dolomite and the Conestoga limestone come to the surface. These limestones are like all other limestones in southeastern Pennsylvania in that they are dense limestones which contain little water except in solution channels. Wells which yield large supplies have encountered solution channels that contain water while those drilled in the solid rock are failures or yield small supplies. The Conestoga limestone is at the surface over most of the area underlain by limestone and is the most important as a water-bearing formation. The Kinzers formation is composed of shale but it is only 50 feet thick

and is unimportant as a source of ground water. In the area underlain by these limestones cisterns for storing rain water are numerous.

The central lowland belt, the elevation of which is from 500 to 600 feet above sea level, is underlain by Triassic deposits. These deposits, described by Stose[1] in the Fairfield-Gettysburg folio, have been separated into two units, the New Oxford formation below and the Gettysburg shale above. The New Oxford formation, named from the exposures around New Oxford in Oxford township in this county, consists of red shale and sandstone with numerous beds of light-colored, micaceous sandstone, arkose, and conglomerates. The coarser sediments are more abundant in the lower 3,000 feet of the formation while the upper 4,000 feet is composed largely of soft red shale and sandstone. The micaceous sandstone is thick and more abundant in the 500 feet near the middle of the formation. The Gettysburg shale, named from the county seat, consists chiefly of thick red shale and soft red sandstone, which has been invaded by a sill of diabase called the Gettysburg sill, which is 1,800 feet thick. Near the middle of the formation, gray to white harder sandstones are numerous and this portion is mapped as the Heidlersburg member on the geologic map in the Fairfield-Gettysburg folio but is not shown on Plate 1. At the top of the formation is the Arendtsville fanglomerate lentil, not named but shown as the Triassic quartzose conglomerate on Plate 1. These conglomerates are composed of pebbles and cobbles more or less rounded, set in a red sandy matrix, which disintegrates rapidly when exposed to weathering. The pebbles are more resistant. In other places the pebbles in the fanglomerate are limestone, marble, dolomite and impure limestone which are set in a fine calcareous red to gray clay or fine sand. The rock is usually compact and firm. The total thickness of the Gettysburg shale is about 16,000 feet exclusive of the diabase sill.

The thicknesses given for the above are total aggregates. The Triassic sediments overlap progressively westward; probably the greatest thickness at any place does not exceed one-half the total.

The Triassic formations are a fairly good source of ground water except in the areas where the rocks are almost entirely shale. Even the shales usually yield supplies of 2 to 10 gallons a minute. These sandstones and shales contain sufficient calcareous material so that the water is quite hard. Springs occur in some localities, but they are not very numerous nor do many of them yield more than 10 gallons a minute. Dug wells have been successful at depths from 20 to 100 feet, but the shallower ones frequently go dry.

Diabase, or "trap", an intrusive igneous rock, is most conspicuous in Adams County. In the vicinity of Gettysburg, where the dikes are thick, the texture is so coarse that the stone is locally called "Gettysburg granite." Diabase usually forms ridges and knobs because it erodes much more slowly than the sedimentary rocks into which it was intruded. Such ridges and knobs are numerous in the vicinity of Gettysburg and most of the prominent topographic features of the Gettysburg Battlefield are due to the resistant character of the diabase. In most places the solid ledges of diabase are not exposed, but the path of the dike is marked by a train of boulders, some of which may be 6 feet, or more, in diameter. On account of the labor necessary to

[1] Stose, G. W. and Bascom, F., loc. cit. pp. 8-11.

remove the boulders, dikes are usually left in woodland and these narrow forested strips run for miles across country.

Diabase is a very compact rock and a poor water horizon. The water is usually obtained at the junction of solid rock and disintegrated material. Consequently, most wells are shallow. The water obtained from the diabase is usually low in dissolved mineral water.

TOWNSHIP DESCRIPTIONS

Latimore, Huntingdon, Reading, and Tyrone townships. The oldest rocks outcropping in these townships are the pre-Cambrian volcanic rocks, which outcrop in South Mountain in the northern part of the county. Few wells have been drilled in these rocks in this area as springs and dug wells adequately supply present needs.

A long belt of Beekmantown limestone is exposed in the vicinity of York Springs. While most drilled wells in the limestone are successful, failures to obtain water will occur. The water is usually hard, but the use of hard water can be avoided by developing springs on the adjacent hillsides.

The Triassic shales and sandstones are at the surface over most of these townships. The famous York Sulphur Spring, one mile southeast of York Springs, once a summer resort, is on Mr. Gardner's property on the south bank of Bermudian Creek. This spring is a small one which yields about 2 gallons a minute. The water has a distinct odor of hydrogen sulphide, but is quite clear. (See analysis No. 3, p. 242.) The water-bearing properties of the Triassic rocks vary greatly. (Nos. 1 to 7 in the following table).

Hamilton, Oxford, Berwick, Conewago, and Union townships. The oldest rocks outcropping in these townships are the pre-Cambrian volcanics exposed in Pigeon Hills and the Harpers phyllite and the Antietam sandstone, both of Lower Cambrian age, the latter largely altered to quartz schist. These rocks yield small supplies to drilled wells.

The Antietam sandstone is overlain by the Cambrian-Ordovician limestone series. The Steacy and Wilton Co., near Bittinger, operates a 1,000 g.p.m. pump to keep the limestone quarry dry. During the drought in 1930 about 450,000 gallons were pumped daily, and in 1933 twice that quantity. The large quarries of the Bethlehem Mines Corporation, at Bittinger, at times pump large quantities of water, but when one considers the areal extent of the quarries, the percolation per unit area is small. Practically all the water enters through solution channels. These limestones usually yield small supplies but some wells are failures. While no data on deep drillings were available, it is improbable that much water will be encountered at depths greater than 250 or 300 feet below the surface.

The limestones, as well as the underlying sandstone and schist, are unconformably overlain by the Triassic sediments. The well at the Hoke Creamery shows that deep drilling may be successful in some places. (No. 9) The Triassic sediments can usually be depended upon to yield small supplies to drilled wells.

Straban, Mount Pleasant, Mountjoy, and Germany townships. These townships are all underlain by Triassic sediments intruded by dikes and sills of diabase. Very few wells in the Triassic sediments are fail-

ures; however, large yields have not been reported from this area but deeper drilling might increase the yields. The data are all on shallower wells. (No. 19 to 24.)

Menallen, Butler, Cumberland, and Freedom townships. The oldest rocks outcropping in these townships are the pre-Cambrian volcanic rocks which are exposed in South Mountain. These rocks outcrop in a rugged, sparsely inhabited area where springs and dug wells adequately supply present needs. From experience in other areas 6-inch drilled wells not exceeding 250 feet in depth should yield small supplies although some wells may be failures.

The Triassic sediments, as well as older rocks, have been intruded by diabase. The well of the Gettysburg Ice and Storage Co. yields 150 gallons a minute although on testing it yielded 200 gallons a minute with a 20-foot drawdown, or a specific capacity of 10. (No. 25.) The water is used for cooling and is reported to deposit calcium carbonate after passing over the condensers.

The Triassic sedimentary rocks can be depended upon to yield small supplies. (Nos. 27 to 33.) In some places small springs issue from the diabase. Some springs that issue from this rock are to be seen on the Gettysburg Battlefield. The one in the Devil's Den is famous because of its use by both sides during the battle.

Franklin, Hamiltonban, Highland, and Liberty townships. The pre-Cambrian volcanic rocks are the oldest ones outcropping in these townships. The volcanic rocks contain numerous quartz veins. (No. 35). The spring of G. A. Kane, at Willow Grove, 3½ miles northwest of Orrtanna, flows 5 gallons a minute. (See analysis No. 37.) A small spring in Cashtown yields about 2 gallons a minute. (See analysis No. 38.) The volcanic rocks can be depended upon to yield water low in dissolved mineral matter. Springs and shallow dug wells are used by the majority of people for their water supply but most new wells are drilled.

Overlying the volcanic rocks are the Cambrian formations, the Weverton sandstone, the Harpers phyllite, and the Antietam sandstone. These formations also outcrop in South Mountain. Springs are the main source of supply. Stillhouse Spring issued from quartzite. (See analysis No. 39.) Springs issuing from the sandstones and quartzites are usually low in dissolved mineral matter and very soft.

The Cambrian and Ordovician limestones, which overlie the Antietam sandstone, outcrop along the eastern side of South Mountain. Little well data are obtainable in this area, but the limestone should yield small supplies except where very dense and large supplies where water-bearing solution channels are numerous.

The largest part of these four townships is underlain by the Triassic sediments with intrusions of diabase. The water-bearing properties are discussed in the preceding group of townships.

DRILLED WELLS IN ADAMS COUNTY

Pub. No.	Owner	Depth	Type	Size	Formation	Yield	Remarks
		Feet		Inches		Gallons per minute	
1	Musselman Canning Co., Gardners	600	Drilled	6	Triassic	10	Water in first 200 feet, shale
2	Hershey Creamery Co., York Springs	200		6	"	10 flow 50 pump	Overflows
5	Borough of East Berlin	910	Drilled	6	"	50	Struck water in first 500 ft. rose to 40.
6	Borough of East Berlin	225	"	6	"	110	Water rose to 30; only 300 ft. from No. 6.
7	Several wells, 1 mi. N. of Oakgrove School	60–100			"	10±	Yellow arkose
8	F. S. Warwick, 3 mi. N. of Hanover	18	Dug	3 ft.	Beekmantown (?) limestone	2	
9	Hokes Creamery, East Berlin	601	Drilled	10	Triassic	75	All enters near bottom; rises to 15 feet.
10	Farmers Picnic Grove, 2.5 mi. N. of Abbottstown	80±		6	"	3	Yellow sandstone
11	Mr. Straszbaugh, near Edgegrove	100		6	Conestoga limestone (?)	1±	Very little water
12	C. R. Altland, Abbottstown	40	Drilled	6	Triassic	3	Red and blue sandstone
13	Waldheim	60±			"		Several wells
14	Mrs. E. Schriver, 1½ mi. E. of New Oxford	55	Dug	5 ft.	"	5	
15	Canning Factory, New Oxford	550		6	"	5	Red shale
16	New Oxford	20–50			"		Wells numerous, good.
17	Frank Beshore, 1½ mi. W. of New Oxford	20	Dug		"	5	Sandstone
18	Frank Beshore, 1½ mi. W. of New Oxford	20	"		"	5	Red shale
19	Frank Beshore, Guldens	40			Diabase	(several)	
20	Gulden Cigar Factory, Bonneauville,	125		6	Triassic	6	Red sandstone
21	Two Taverns	90		6	"	4	
23	Mr. Benner, 1¾ mi. N. W. of Two Taverns	125		6	"	7	Red shale
24	Mr. Benner, 1½ mi. N. W. of Two Taverns	155		6	"	2½	Numerous dug wells, dry.
25	Gettysburg Ice & Storage Co., Gettysburg	400		8	"	200	Most water at 300 feet rises to 30 feet.
26	Gettysburg Ice & Storage Co., Gettysburg	232		6	"	60	Cooling
27	Lutheran Seminary, Gettysburg	125		6	"	7	
28	Arthur Shields, 1¾ mi. N. W. of Gettysburg	80		6	"	5	
29	Miller's Camp, 2 mi. N. W. of Gettysburg	40	Drilled	6	"	3	Shale
30	Miller's Camp, 2 mi. N. W. of Gettysburg	55	"	6	"	4	"
31	Miller's Camp, 2.1 mi. N. W. of Gettysburg	60	"	6	"	5	"
32	Mr. Eck, 2.25 mi. N. W. of Gettysburg	60	"	6	"	5	Blue shale
33	Mr. Eck, 2½ mi. N. W. of Gettysburg	60	"	6	"	2	Shale
34	L. E. Hershey, 3½ mi. N. W. of Gettysburg	36	"	6	Diabase	4	
35	A. M. P. Maschmeyer, 6 mi. N. W. of Orrtanna	76		6	Pre-Cambrian	5	Vein quartz

BERKS COUNTY

GENERAL CONDITIONS

Berks County is divided subequally by the Schuylkill River and is bounded by Lehigh, Montgomery, Chester, Lancaster, Lebanon, and Schuylkill counties. Its area is 865 square miles, and the population according to the United States Census of 1930 is 231,717, of which 111,171 live in Reading, the county seat. The number of inhabitants per square mile is 268 as compared with 214.8 for the entire State. The same census gives the percentage of rural population as 39.4 and the rural population per square mile as 105.4. These figures indicate that the county is no longer dominantly rural but due to the growth of the industrial cities and towns, the urban dwellers outnumber the rural. In recent years many new suburban developments have been built in the vicinity of the larger towns and cities beyond the reach of the city water supplies. Consequently ground-water supplies are very important.

Geologic column in Berks County

Age	Name and description	Water-bearing properties	Thickness
TRIASSIC	Sandstone and shale, arkoses and conglomerates. Mostly of red color.	Sandstones yield supplies up to 100 gallons a minute.	?
	Calico rock. Limestone pebbles in red sandy matrix.	Small supplies of hard water.	?
ORDOVICIAN	Martinsburg shale. Shale and slates.	Small supplies from shales, the slates somewhat larger yields.	3,000±
	Beekmantown limestone. Heavy bedded magnesian limestone.	Large yields where cavernous, small yields where solid.	1,000±
CAMBRIAN	Conococheague (Allentown) limestone. Dolomitic and sandy limestone.	Similar to Beekmantown.	1,500±
	Tomstown limestone. Limestone and shale.	Most wells yield small supplies.	1,000±
	Hardyston quartzite, Sandstone, quartzite, mica and quartz schist and conglomerate.	Usually yields small supplies of very good water.	40–300
PRE-CAMBRIAN	Franklin limestone. Coarse, crystalline limestone containing considerable graphite.	Should yield small supplies.	150(?)
	Pickering gneiss, graphitic gneiss.	Small supplies.	(?)

Igneous rocks

TRIASSIC	Diabase or "trap rock." Fine-grained dark gray crystalline rock.	Small supplies at shallow depths.	(?)
PRE-CAMBRIAN	Gabbro. Dark green coarse-grained hornblende gabbro.	Small yields. Numerous.	(?)

Pickering gneiss. Pickering gneiss is the name given to a graphitic gneiss with which are associated other gneissic rocks, all of equally obscure origin. These rocks outcrop chiefly in the uplands of the southern part of the county. The gneiss is a poor source of ground water, and drilled wells yielding more than 10 gallons a minute are unusual.

Franklin limestone. This limestone is usually very dense and consequently yields but little water when penetrated by drilled wells. Its areal extent is small and consequently is of little importance in discussing the ground-water problems of the county.

Hardyston quartzite. The Hardyston quartzite which rests unconformably on the eroded pre-Cambrian crystalline rocks is approximately the equivalent of the Chickies quartzite and the Weverton sandstone, and is Lower Cambrian in age. This formation consists of pure quartzite with some interbedded argillaceous sediments now metamorphosed to light-colored mica schists. These rocks are all dense and thoroughly cemented with little or no pore space. Consequently, they yield but little water to wells drilled in them, and failures to obtain water occur frequently.

Tomstown limestone. The Tomstown limestone is like the other "Valley limestones" in that it yields but little water where wells encounter solid rock and large supplies where the wells intersect solution channels filled with water.

Conococheague limestone. The Conococheague limestone, or as it is known locally, the Allentown limestone, is a prominent limestone which outcrops in the middle of the valley except where cut out by faulting. It usually contains numerous *Cryptozoon proliferum,* the stony skeletons of calcareous algae which, in cross-section, appear to be piles of tightly packed, upwardly curved laminae and when viewed from above as series of knobs or bumps one-half to 1 inch high on the flat surfaces of the limestone. This limestone is generally high in magnesium. The magnesian layers weather white and give the rock a banded appearance. The siliceous layers weather in relief and also produce a banded appearance.

The water-bearing properties of this limestone resemble those of the underlying Tomstown limestone.

Martinsburg shale. The Martinsburg shale, which overlies the Beekmantown limestone, consists of about 3,000 feet of dark gray to black fissile shale with some thin, greenish-gray sandstone, chiefly in the middle and with some argillaceous blue limestone lenses at the base. The openings along the cleavage, bedding, and joint planes, usually yield adequate water supplies for domestic purposes, but large industrial and municipal supplies are rarely obtainable.

TOWNSHIP DESCRIPTIONS

Hereford, District, Pike, and Washington townships. Hereford, District, Pike, and Washington townships are situated in the Reading prong of the pre-Cambrian schist, gneiss, gabbro, and granite area. The four townships are in a rough upland region which is not thickly inhabited except in the valleys which have been formed by the erosion of faulted blocks of limestone. The crystalline rocks, which in many places retain their cap of Hardyston quartzite, supply water to numerous springs and occasional dug wells which are adequate to supply the present population. Data concerning drilled wells in this area are not available, but it is probable that drilled wells will yield small supplies at depths not exceeding 250 feet. In some instances wells may be failures.

The Hardyston quartzite is overlain by the Tomstown dolomite. When a well at Barto (No. 3) is pumped at a high rate the water becomes turbid, indicating that it draws water from mud-laden solution channels. This and other wells indicate that the limestone in Washington Township is sufficiently cavernous to yield small supplies of 10 to 12 gallons a minute to wells ranging in depth from 100 to 250 feet. Whether openings exist at greater depths and would yield large supplies still awaits an adequate test by deeper wells.

Richmond, Maxatawny, and Longswamp townships. The crystalline rocks outcrop in the southern part of Richmond, Maxatawny, and Longswamp townships. The water-bearing properties of these rocks are discussed under the preceding townships. Wells No. 4 to 9 indicate the variable conditions met in limestone areas. In most instances wells in limestone require relatively little casing, but at Topton, (Nos. 4 and 5) 200 feet, or more, were necessary. At Kutztown solution channels yield very large supplies, while wells which do not intersect them are failures (Nos. 6 and 8). While the one 800-foot well (No. 6) does not condemn deep drilling in this area, it is a warning that failure may attend some of the future attempts. Richmond Township has numerous sink holes which indicate the presence of underground channels.

The northern parts of Richmond and Maxatawny townships are underlain by the Martinsburg shale. The shale forms rounded hills which stand out conspicuously when compared with the open lowlands of the valleys underlain by limestone. The shale, or "slate," as it is locally called, furnishes small supplies adequate for domestic use. Drilled wells are not numerous in this area, and little data concerning them were available. Dug wells 4 and 5 feet in diameter and 50 to 100 feet deep are very common. On account of the hardness of the water many people use cisterns to catch rain water for laundry purposes.

Ruscombmanor, Rockland, and Oley townships. The oldest rocks outcropping in Ruscombmanor, Rockland, and Oley townships are the crystalline rocks of pre-Cambrian age, which, due to resistance to erosion, form the rough uplands. The borough of Fleetwood is situated in Richmond Township and is underlain by limestone. To obtain soft water, a group of five springs 1½ miles south of the borough, along Willow Creek, was improved and the water piped to a 175,000-gallon reservoir. To augment this supply another group of five springs has been improved and piped to the same reservoir. The combined yield of the springs is less than 100 gallons a minute. The village of Lyon Station in Maxatawny Township is underlain by limestone. Nine springs half a mile south of the village are piped to reservoirs and the water distributed by gravity. These towns, located in the limestone valley, have taken advantage of the springs in the uplands to obtain soft water under sufficient head that it can be distributed by gravity.

The village of Bowers, although in Maxatawny Township, also obtains its water supply from the crystalline rocks in Rockland Township from a large spring 1 mile south of the village. The water is piped to a 10,800-gallon reservoir at an elevation of 100 feet above the village and distributed by gravity.

Little difficulty should be experienced in obtaining small supplies from the crystalline rocks by drilling wells less than 200 feet in depth, except where the wells are unfavorably situated.

The crystalline rocks are overlain by the Hardyston quartzite. However, erosion has removed much of the quartzite, and the remaining areas form rough uplands.

The Hardyston quartzite is overlain by limestones of Cambrian and Ordovician age. These rocks, due to lower resistance to erosion, particularly erosion by solution, form the valley in Oley Township. The water-bearing properties of the limestone are discussed under the preceding townships. A number of springs issue from the limestone in the eastern part of the township.

Earl, Colebrookdale, Amity, and Douglass townships. Pre-Cambrian crystalline rocks occur at the surface in parts of Earl, Colebrookdale, and Douglass townships but in Amity Township these old rocks are overlain by the Hardyston quartzite, the Cambrian and Ordovician limestones, and, in places, by the red sandstones and shales of Triassic age.

The borough of Boyertown obtains its water supply from the crystalline rocks. It utilizes several groups of springs about 2¼ miles northwest of the borough. The total yield of these springs is approximately 200 gallons a minute. Small springs and dug wells furnish adequate supplies for the population of the uplands and few wells have been drilled. However, drilled wells should yield small supplies of excellent water, usually less than 10 gallons a minute. Some wells may be complete failures, but the failures should not exceed 5 per cent.

The Hardyston quartzite, which overlies the crystalline rocks, is treated as part of them. However, where the water supplies are obtained from this quartzite the quality is better than that obained from the underlying pre-Cambrian rocks.

The Hardyston quartzite is overlain by limestones of Cambrian and Ordovician age, which outcrop to the south of Boyertown. These limestones were encountered in magnetite mines at Boyertown, and when drilled into, during the process of deepening a mine shaft, large volumes of water under considerable pressure were obtained, according to J. Ross Corbin, superintendent, Boyertown Iron Ore mines in 1916-17.

The limestones are overlain by rocks of Triassic age, which consist chiefly of red sandstones and shales with subordinate amounts of other types of rock. Wells ending in these rocks indicate that small supplies are usually obtainable at depths ranging from 70 to 150 feet, but in some cases it may be necessary to drill to 250 feet to obtain sufficient water for domestic use (Nos. 10 to 17). In many instances industrial supplies can be had at depths not exceeding 350 or 400 feet. The water is usually under some artesian pressure, but in most wells it stands so far below the surface of the ground that deep well pumps are necessary.

Diabase, or "trap," also of Triassic age, outcrops in the vicinity of Boyertown. The trap rock is itself a poor water horizon and wells drilled in it rarely yield more than a few gallons a minute. The water is usually low in mineral matter. However, the dikes hinder the circulation of ground waters in the rocks which they intrude.

Albany, Greenwich, Windsor, and Perry townships. Almost the only rock outcropping in these townships is the Martinsburg shale. Usually this shale yields small supplies to drilled wells at depths not exceeding 250 feet. However, two drilled wells at the Hamburg reser-

voir are reported to yield large supplies. Well No. 1, 8 inches in diameter, 302 feet deep, yields 100 gallons a minute; Well No. 2, nearby, 8 inches in diameter, 220 feet deep, yields 208 gallons a minute. These wells are better than most wells in the Martinsburg shale except where the shale has been metamorphosed to slate. These wells may get their supply from sandy beds near the middle of the formation. Wells drilled in the shale are rarely complete failures. The Leesport "cement rock" crops out in Perry township, but well data were not available for this area.

Ontelaunee and Maiden Creek townships. Both Ontelaunee and Maiden Creek townships lie chiefly in the limestone valley between "slate hills" formed by the Martinsburg shale on the north and the hills formed by the crystalline rocks on the south. The water-bearing properties of these formations are discussed under Richmond, Maxatawny, and Longswamp townships. The Leesport "cement rock" also crops out in this area, but as in the preceding group of townships, well data were not available.

Muhlenberg, Alsace, and Lower Alsace townships. The oldest rocks outcropping in Muhlenberg, Alsace, and Lower Alsace townships are the pre-Cambrian crystalline rocks. Wells in the borough of Hyde Park indicate that difficulty may be experienced in obtaining supplies from the crystalline rocks (Nos. 18, 19, and 20).

The city of Reading obtains its water from various sources, principally from Maiden Creek. Part of the supply is from springs in the mountains east of the town. These springs issue from the pre-Cambrian crystalline rocks. Springs in the Hardyston quartzite, as well as a collecting gallery on the mountain, also yield a small volume of water. In most places, however, wells drilled in the crystalline rocks usually obtain small supplies at depths not exceeding 250 feet.

The pre-Cambrian crystalline rocks are overlain by the Hardyston quartzite, which does not yield water abundantly to most wells (No. 21.)

The Hardyston quartzite is overlain by the limestones of Cambrian and Ordovician age. The well at the Merchants Ice Co., in Reading, (No. 22) has 185 feet of casing and the water rises to within 55 feet of the surface. The drawdown is 4 feet giving a specific capacity of 100 gallons a minute. The well of the Dane Manufacturing Co. in Reading encountered a 15-foot opening (No. 23). The capacity of this well is estimated to be several times the rate at which it is now pumped. The well of the Nolde & Horst Knitting Mills (No. 24) encountered two large openings near the bottom—one 9 feet and the other 12 feet.

Log of 250-foot well of the Reading Cold Storage Co. (No. 26)

	Thickness Feet	Depth Feet
Clay, chert, and sandstone	130	130
Limestone	50	180
Sandstone	15	195
Limestone, fissured	55	250

The group of wells in the city of Reading (Nos. 22 to 29) indicate that large supplies of water can be obtained from the limestones but that chances of failure exist. Apparently wells exceeding 400 or 500

feet in depth do not yield sufficiently large volumes of water to justify their cost. The village of Muhlenberg Station is supplied by Mammoth Spring Water Co. from two large springs near the mouth of Laurel Run, which have a combined minimum flow estimated at 1,250 gallons a minute.

The sediments of Triassic age transgress the pre-Cambrian as well as the Cambrian and Ordovician rocks. These beds, predominantly red in color, form a striking contrast to the older deposits. The Mount Penn Suburban Water Co. utilizes two drilled wells (Nos. 30a. 30b), as well as springs in the Hardyston quartzite. These two wells show that industrial and municipal supplies can be obtained from the Triassic beds.

Exeter Township. The oldest rocks outcropping in Exeter Township are the pre-Cambrian crystalline rocks, which are at the surface in the uplands of the northern part of the township. These rocks usually furnish small supplies to drilled wells, but some failures will occur. Present needs are largely supplied by small springs.

The crystalline rocks are overlain by the Hardyston quartzite. The village of St. Lawrence obtains its supply from springs issuing from the quartzite in Gulden Hill. The water is reported to be soft. The quartzite is hard to drill, but usually yields small but excellent supplies.

The Hardyston quartzite is overlain by limestones of Cambrian and Ordovician age. The Reading Country Club, on the Philadelphia road about 5 miles east of Reading, has a large spring which yields about 150 gallons a minute. This spring is surrounded with a masonry wall and is equipped with a Gould triplex pump, gear connected to a 10-horsepower motor. The water supplies all the needs about the club, including watering greens. (See analysis No. 32).

The limestones are in most places covered with Triassic sandstones and shales of predominantly red color. In addition to the sandstones and shales there are outcrops of a conglomerate composed of limestone pebbles, derived from the Cambrian and Ordovician limestones and cemented by red sandy material. These beds are locally called "calico rock." Another name is "Potomac marble." A number of wells have been drilled in this conglomerate along the Philadelphia road southeast of Mount Penn, and all have yielded enough water for domestic use (Nos. 33, 34). Due to the presence of limestone, water from these wells is hard, but in the sandstones and shales the water is softer (No. 35). The Triassic sedimentary rocks usually yield small supplies at shallow depths and frequently industrial supplies of 100 gallons a minute, or more, can be obtained. The availability of such large supplies has not been proved in this township.

Triassic diabase occurs in this township, but it is of small importance as a source of ground water.

Exeter Township is building up rapidly along Route 422, both with developments and isolated houses. Great care should be exercised in developing water supplies in order to avoid contamination.

Robeson, Union, and Caernarvon townships. These townships are everywhere underlain by both sedimentary and igneous rocks of Triassic age, except in the extreme southern end of the last named town-

ship where the early Paleozoic limestones are exposed in the valley around Morgantown, and the Chickies quartzite and the pre-Cambrian crystalline outcrop in Welsh Mountain. The area of crystalline rocks outcropping in Caernarvon Township is so small that these rocks are of little or no importance as a source of ground water. The crystalline rocks are overlain by the Chickies quartzite, including its basal Hellam conglomerate member. Few wells have been drilled in these rocks, but some of the small springs issuing from them are piped to the valley. A spring on the property of Ira Peterschein, 1¼ miles southeast of Morgantown, is piped one-fourth of a mile to the house and furnishes an abundant supply of soft water under pressure.

The Chickies quartzite is overlain by limestones. A limestone spring on the property of Stephen Stolzfus, half a mile east of Morgantown, yields approximately 10 gallons a minute. This spring, which issues from the limestone, is well improved and part of the water is used to operate a hydraulic ram that lifts the remainder up to a tank to furnish water for the house. (See analysis No. 37).

The limestones are overlain unconformably by Triassic sediments. The well at the Morgantown Water Co's reservoir (No. 39) is used to supplement the flow of springs which issue from the arkosic sandstones of the Stockton formation. The water from the springs and the well flows from the reservoir to the town and is distributed by gravity. The spring of D. B. Gates, 2 miles north of Beckersville, yields 5 gallons a minute. This hillside spring is well improved with a large stone spring house. (See analysis No. 49). Birdsboro, in addition to using surface water, also uses some springs issuing from the Triassic rocks, the total yield of which is about 50 gallons a minute. The several sedimentary formations of Triassic age are fairly good ground-water horizons. The sandstones in general yield larger supplies than the shales. If the shales are compact and joints are not developed the wells may yield very little water. In places it may be necessary to case the wells to depths of 100 feet or more. The successful wells average about 150 feet in depth, and little or no data are available concerning the yield of deeper wells. The results obtained in adjacent areas suggest that supplies up to 100 gallons a minute might be obtained in these townships from wells not exceeding 500 feet in depth.

Diabase, "trap rock," is unimportant as a source of ground water in these townships.

Tilden, Upper Bern, Center, Penn, and Bern townships. The Martinsburg shale is the only formation outcropping in these five townships except in the southeastern part of the last named township where erosion has exposed the underlying "cement rock" and limestone. No well data were available in the area where the "cement rock" comes to the surface. The water-bearing property of the limestone is the same as in adjacent townships.

The Martinsburg shale is known locally as the "black slate," and forms rolling uplands some 100 to 300 feet above the limestone valley. Usually wells in this shale yield from 5 to 10 gallons a minute, and show considerable fluctuation of the water table (Nos. 50 to 52.)

Lower Heidelberg and Spring townships. The oldest rocks outcropping in Lower Heidelberg and Spring townships are crystalline

rocks of pre-Cambrian age. They outcrop in South Mountain. These schists, gneiss, and intruded igneous rocks are, in places, overlain unconformably by the Hardyston quartzite. A number of wells have been drilled at summer homes in the mountains, and some of these wells are in the quartzite, while others are in the crystallines (Nos. 53 to 66). The water-bearing properties of the quartzite and the crystalline rocks are similar. The waters issuing from the former are generally lower in dissolved mineral matter. The Grand View Sanatorium utilizes springs above its buildings. A nearby mineral spring called the Pavilion is used for drinking water. The Walter Sanatorium has developed several groups of springs and uses them for all purposes. Wernersville has improved six springs which yield about 15 gallons a minute each and this supply is supplemented by a drilled well 80 feet deep which yields 180 gallons a minute. The water is piped to a storage reservoir and distributed by gravity. This gives the borough a supply of soft water.

The Hardyston quartzite is overlain by the limestones of Cambrian and Ordovician age, which outcrop in the valley between South Mountain and the "slate hills." According to the driller, a well at West Reading (No. 69) was drilled through 60 feet of shale, 160 feet through slate, and the remainder in limestone. The drill dropped into an 8-foot opening at 468. Sinking Spring, Wyomissing, and West Reading obtain part of their water supply from Gring Spring in South Mountain, but the remainder is obtained from the Yost and Wyomissing springs which issue from limestone. Glenside obtains water from drilled wells. Limestone wells in these townships are like those in the limestone in other regions (Nos. 67 to 76).

The limestones are overlain by the Martinsburg shale. The well of Mr. Klupp is typical of wells in the Martinsburg shale (No. 77). In some places the water is hard and rain water is caught and stored in cisterns to supply soft water for laundry use.

The crystalline rocks are overlain by the Triassic sediments. The water-bearing properties of these beds are discussed under Robeson, Union, and Caernarvon townships.

Cumru and Brecknock townships. All of Cumru and Brecknock townships are in the belt of Triassic rocks except the northern end of the former where the Cambrian and Ordovician limestones come to the surface. The great variation in ground-water possibilities in limestone is shown by wells at Shillington (Nos. 78 and 79) which are only a short distance apart.

The limestones are overlain by sedimentary deposits of Triassic age, which consist chiefly of red sandstone and shale with some coarse arkosic beds near the base of the series. Into these beds diabase has been intruded in the form of dikes which are numerous in Brecknock Township. The well of Mr. Hess at Gouglersville is representative of several wells in the village (No. 80). The boroughs of Mohnton and Shillington and the village of Edison are supplied with water by the Mohnsville Water Co. The water is obtained partly from surface streams and partly from wells and springs. A drilled well located just west of Mohnton yields 60 gallons a minute. A group of small springs south of the borough have been improved and their yield is augmented by a collecting gallery driven into the mountain.

Bethel, Tulpehocken, Upper Tulpehocken, and Jefferson townships. The formation with which this report is concerned that occurs in these four townships is the Martinsburg shale. The 6-inch drilled well of Frank Muck, at Mt. Etna, is 80 feet deep and yields 15 gallons a minute. The water stands 40 feet below the surface. Apparently supplies of water up to 40 gallons a minute can be obtained from the shale by drilling wells 80 to 110 feet deep. In some places, however, it may be necessary to drill at least 250 feet to obtain supplies adequate for domestic purposes. On account of the hard water obtained from the shale many farms are equipped with cisterns for storing rain water.

Marion, Heidelberg, and North Heidelberg townships. The oldest rocks outcropping in Marion, Heidelberg, and North Heidelberg townships are the pre-Cambrian crystalline rocks in South Mountain. These crystalline rocks are overlain by the Hardyston quartzite. Womelsdorf and Robesonia are supplied by private corporations which obtain water from Gold Spring which issues from the quartzite about 2½ miles south of Womelsdorf and has a yield of 70 gallons a minute with some fluctuations, depending on the season. The water flows into a large reservoir on the mountain side and is distributed to both boroughs by gravity. The water-bearing properties of these rocks are discussed under Lower Heidelberg township.

The Hardyston quartzite is overlain by the Cambrian and Ordovician limestones. While supplies up to 100 gallons a minute can be obtained from wells in the limestone (Nos. 84 to 92), failures are reported to be somewhat more numerous in this area than in adjacent townships.

DRILLED WELLS IN BERKS COUNTY

Pub. No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1		Bechtelsville	125±	6	Tomstown dolomite		10-12	Numerous wells.
2		Eschback	125±	6	do		10-12	do
3		Barto	250	6	do		10	Heavy pumping makes water muddy.
4	H. Ervin Sons Paint Mgf. Co.	Topton	250	8	do	170	100	200 feet of casing.
5	Borough of Topton	do	252	8	do	150	100	220 feet of casing.
6	Light & Power Company	Kutztown	800	6	Beekmantown limestone		8	Water enters at 90 feet.
7	do	do	150	6	do		dry	500 yards from No. 6.
8	Borough of Kutztown Crevice in quarry	do			do		100±	Pump placed in quarry.
9	Drilled well	do	42	12	do	5	500	Practically no drawdown.
10	Hotel	New Berlinville	90	6	Gettysburg shale		10	
11		do	70-100	6	do		5-10	Numerous wells.
12	Shaner	Boyertown	85	6	do		8	Iron ore encountered.
13	Harbison Creamery	do	150	6	do		20	
14	Max Rutter	Pine Forge	260	6	do	220	10	Water enters near bottom.
15	Harbison Creamery	Douglassville	350	8	do	40	75	Red shale and sandstone.
16	Harry Scherr	do	250	6	do		50	do
17		do	125±	6	do		6-8	Numerous wells.
18	St. Michael's Convent School	Hyde Park	984	6	Granite		dry	Dry.
19	do	do	500	6	do		6	[illegible]
20	do	do	435	6	do		14	Most of the water comes from upper 250 feet.
21	J. Berkert	1½ miles NE. of Mt. Penn	185	6	Hardyston quartzite	80	15	
22	Merchants Ice Co.	Reading	245	8	Conococheague limestone	55	400	See text.
23	Dane Manufacturing Co.	do	260	8	do		120±	do
24	Nolde & Horst Knitting Mills	do	300	8	do		300	do
25	Reading Cold Storage Co.	do	800	8	do		0	Dry hole in solid limestone.
26	do	do	250	10	do	80	225	300 feet north of No. 25. See log of well.
27	St. Lawrence Dairy	do	300	6	do	30	90	
28a	Reading Paper Mills	do	600	6	do		90	
28b	do	do	400		do		90	
28c	do	do	200		do		90	

29	Reading Ice Cream Co.	do	160	6	Tomstown limestone		30	
30a								
30b	Mt. Penn Suburban Water Co.	Mt. Penn	300	8	Gettysburg shale		200	Two wells.
31	Swatara Hotel	Baumstown	175	6	do	80	15	Water enters near bottom.
33	Harry Althouse	1 mile SE. of Mt. Penn	102	6	do	40	30	"Potomac marble."
34		1 mile SE. of Mt. Penn	95±	6	do		25	"Potomac marble"; several wells.
35		.6 mile SE. of Mt, Penn	300	6	do	60	10	Red shale; water enters near bottom.
38	David Mast	¾ mile S. of Morgantown	310	6	Beekmantown limestone	28	8	Water at 50, 295, and 305 feet
39	Morgantown Water Co.	¼ mile S. of Morgantown	310	6	Gettysburg shale	10	21	
40	Harmony School House	Harmony Church	65	6	do	40	10	
41	T. A. Gerhardt	Plowville	100	6	do	80	5	20 feet of casing; see analysis
42	Daniel Seifert	do	75	6	do	30	10	Water enters near bottom; 65 feet of casing
43	Mr. Segner	do	125	6	do		20	
44	Mr. Spu tle	¾ mile NW. of Beckersville	43	6	do	5	12	Water enters near bottom
45	John Good	1¾ miles NW. of Scarlets Mill	84	6	do		7	20 feet of casing
46	E. & G. Brooke Iron Co.	1 mile NE. of Scarlets Mill	80	6	do		20	White sandstone reported
47	Henry Brady	Scarlets Mill	70	6	do		15	45 feet of casing; see analysis
48	Charles Geiger	do	60	6	do		20	
50	Mr. Groover	Obold	80	6	Martinsburg shale		15	
51	Hershey Chocolate Co.	do	180	6	do		35	
52	Bakery	Bernville	60	6	do	10	20	Shale grades into limestone near bottom
53	Highland House	Highland	120	6	Martinsburg shale	40	35	Iron streaks
54	Mr. Kendig	do	90	6	Pre-Cambrian		20	
55	Sunset House	do	546	6	Hardyston quartzite	145	60	Conglomerate
56	George S. Pomeroy	do	1,069	8	do	30	5	Water enters at 90 feet; dry hole from 90 feet to bottom
57	do	do	200	8	do		40	Conglomerate; iron ore encountered
58		do	80	6	do		15	Across road from No. 57
59	Sunset Hall	do	400	6	do		0	Conglomerate; dry hole
60	do	do	600	6	do		12	Conglomerate; near to No. 59

Pub. No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
61	Mr. Beutonwood	½ mile NW. of Fritztown	300	6	do		5	Conglomerate
62	do	do	250	6	do	12	80	Sandstone
63	Albert Proston	½ mile SW. of Fritztown	325	6	do	150	25	Passes through 250 feet of clay and ends in sandstone
64	George Johnson	½ mile SW. of Fritztown	280	6	do	170	15	220 feet of clay, 60 feet of sandstone
65		Fritztown	90±	6	do		20	6 wells; cased to bottom
66	Gring's Sand Quarry	1 mile SE. of Sinking Spring	265	6	do	150	15	Sandstone
67	Bert Wilson	½ mile N. of West Reading	600	6	Beekmantown limestone		0	Dry hole
68	do	do	250	6	do	60	100	
69	Glen Gery Shale Brick Co.	West Reading	476	6	Conococheague limestone		60	Last 8 feet open
70	Henry Weldy	½ mile E. of West Lawn	180	6	do		60	80 feet of shale, then limestone
71	Stitzer Apartments	Sinking Spring	101	8	Beekmantown limestone		150	Now a cesspool
72		Montello	125	6	Conococheague limestone		20	Numerous wells
73	Pomeroy Country Club	1 mile NW. of Sinking Spring	300	6	Beekmantown limestone	6	150	Water for swimming pool
74		1 mile W. of Sinking Spring	90	6	do		20	Sandy shale
75	Mr. Bur man	1½ miles W. of Wernersville	85	6	do	30	20	
76	Moyer Brothers	1¾ miles W. of Wernersville	99	6	do	30	20	
77	Mr. Klupp	½ mile NE. of Wernersville	90	6	Martinsburg shale		5	Slate
78	Shillington Hosiery Mill	Shillington	70	8	Conococheague limestone	30	60	Fissures encountered
79	do	do	560	6	do		0	100 feet north of No. 78; dry, drilled through limestone into sandstone
80	Mr. Hess	Gouglersville	125	6	Gettysburg shale	50	15	Water enters in red shale near bottom
81		1½ miles W. of Beckersville	100	6	do		30	Two wells on opposite sides of road
82	Fire Engine House	Rehrersburg	110	6	Martinsburg shale		40	Sandy, yellow shale
83	Frank Muck	Mt. Etna	50	60	do	40	10	Dug well; see analysis
84	John Hollenbach	Robesonia	300	6	Beekmantown limestone		0	Dry hole in solid rock

85	Mr. Ruth	do	46	6	do		20	Fractured limestone
86	Mr. Fox	Womelsdorf	90	8	do		100	Abandoned, and used for cesspool
87	Williams & Moyer Paper Box Factory	do	400	6	do		0	Dry hole
88	Mr. Williams	do	220	6	do		8	
89	James Hill	¾ mile E. of Stouchsburg	300	6	Stones River limestone		0	Dry hole
90	do	do	80	6	do		15	Only 50 feet from No. 89
91	Dr. Ruth	Stouchsburg	120	6	do		5	Shaly limestone
92	John Ruth	do	80	6	do		20	

BUCKS COUNTY

GENERAL CONDITIONS

Bucks County is bounded on the east by Delaware River, which separates it from the State of New Jersey, and is surrounded on the remaining sides by Northampton, Lehigh, Montgomery, and Philadelphia counties. Its area is 608 square miles, and its population, according to the United States census of 1930 is 96,727, or 519 persons per square mile. The same census reports 4,383 farms in the county. The rural population and a considerable portion of the urban population depend upon ground water. Morrisville is the only large borough in the county depending entirely upon surface water.

Bucks County is a prosperous agricultural region which produces a variety of products that find a ready market in Philadelphia. Incorporated and unincorporated towns and villages are numerous. Many of these towns contain mills and factories as well as mercantile establishments, which add to the general prosperity of the region.

Over most of the county surface streams are numerous, but few, if any, of them are fit for general water supply without filtration and chlorination. Ground water has long been the main supply of the region, with springs and dug wells as the usual sources. In recent years most new wells are drilled. In this county the yield of wells ranges from nothing to several hundred gallons a minute, depending upon depth, size, and water-bearing properties of the aquifer.

GEOLOGY OF BUCKS COUNTY

The geology of Bucks County is essentially a discussion of the Triassic formations which are at the surface over most of the county. In the extreme northern and southern parts of the county the older rocks come to the surface. Erosion has also exposed a narrow belt of Cambrian and Ordovician limestones between Doylestown and Center Bridge. These limestones doubtless underlie the Triassic sediments in most places at unknown depths. Quaternary deposits are present in the extreme southern part of the county along Delaware River. Concealed beneath them may be unconsolidated Cretaceous sediments.

For the convenience of those persons using this section of the report the following geologic column is inserted:

Geologic column of Bucks County[1]

SEDIMENTARY ROCKS

Age	Name and description	Thickness	Water-bearing properties
Quaternary	Terrace deposits. Sand, clay, and gravel.	0–40	Thin and unimportant except in southern part of area.
Triassic	Brunswick shale. Chiefly soft red shale.	12,000	Yields small supplies. A few wells exceed 100 gallons a minute.
	Lockatong formation. Dark hard shale, fine-grained sandstone and flagstones.	3,000–3,500	The poorest ground-water horizon in the Triassic group. Domestic supplies usually available.
	Stockton formation. Gray sandstone, arkose, and red shale.	3,000	Wells usually successful. Some yield 200 gallons a minute, or more. Best ground water horizon in the county.
Ordovician	Cocalico phyllite Chiefly dark phyllite with subordinate beds of quartzite, slate, and arkosic sandstone.	500+	Wells in this formation yield small supplies.
	Beekmantown (?) limestone. Chiefly light blue magnesian limestones and dark fine-grained dolomite.	1,000±	Yield depends upon wells intersecting water-bearing solution channels. Wells in solid limestone yield little water.
	Unconformity		
Upper Cambrian	Conococheague limestone. Massive blue limestone with siliceous partings and light blue dolomite with wavy shaly partings.	900±	Yield depends upon wells intersecting water-bearing solution channels. Wells in solid limestone yield little water
Upper and Middle Cambrian	Elbrook limestone. Gray finely laminated to shaly, earthy limestone with black chert.	500±	
Lower Cambrian	Tomstown dolomite. Massive dark blue dolomite.	500±	Yield depends upon wells intersecting water-bearing solution chemicals.
	Chickies quartzite, granular quartzite and conglomerate.	270±	Yields small supplies of excellent water.
	Hardyston quartzite[2]. Sandstone, conglomerate, and quartzite; white to yellow.	20–300±	Yields small supplies of excellent water.
Pre-Cambrian	Wissahickon formation. Micaceous gneiss and schist.	?	Yields small supplies.
	Baltimore gneiss. A complex gneiss in places containing graphite.	?	Yields small supplies of fairly good water..

IGNEOUS ROCKS

Age	Name and description	Thickness	Water-bearing properties
Triassic	Diabase, dark gray mainly fine-grained crystalline rock occurring in dikes.	?	Yields small supplies from shallow depths.
Pre-Cambrian	Gabbro, coarse-grained dark colored crystalline rock. Occurs in intrusive masses in Baltimore gneiss.	?	Yields small supplies. Poor and uncertain water horizon.
	Granite, includes some gneissic rock.		Yields small supplies. Poor water-bearing formation.

[1] This geologic column was compiled from columns in Trenton folio and Bulletin 828. Bascom, F., & others, U. S. Geol. Survey Geol. Atlas, Trenton folio (No. 167) 1909. Bascom, F., & others, Geology and mineral resources of the Quakerstown-Doylestown District, Pennsylvania and New Jersey: U. S. Geol. Survey Bull. 828, 1931.
[2] The Hardyston does not underlie Chickies but is equal to Chickies near Delaware River.

The typical Baltimore gneiss occurs in a narrow strip in the extreme southeastern part of the county. In the northern part a similar gneiss, which, however, is quite graphitic, is exposed in South Mountain. This graphitic gneiss is considered to be the same as the typical Baltimore gneiss, which is in places graphitic, and their water-bearing properties are much the same. The Baltimore gneiss is the oldest rock exposed in the area, and the succeeding sedimentary formations rest on it as a basement and into it are intruded the igneous rocks of the region. The gneiss is not a good water horizon, but, on the other hand, few wells ending in it are failures. In most places drilled wells yield small supplies at depths ranging from 50 to 250 feet. Many wells draw their supplies from the contact of the partially disintegrated rock and the fresh rock. This zone lies from 10 to 60 feet below the surface. Joint and fault planes extend to greater depths but below that depth even these openings tend to disappear or the openings are reduced so materially that they no longer afford space for accumulation and circulation of ground water.

The Wissahickon formation, which overlies the Baltimore gneiss, consists of schist and gneiss in which muscovite is a prominent mineral. It is at the surface in the southern part of the county. Wells in this formation usually yield small supplies although some wells yield 100 or more gallons per minute.

The Chickies quartzite outcrops in a narrow band in the southern part of this county and forms a series of hills. Wells in the quartzite usually yield small supplies of very good water. The Hardyston quartzite, of Lower Cambrian age, outcrops in Durham and Buckingham townships. This formation consists of sandstone and conglomerate which has been metamorphosed to quartzite. In some places it also contains considerable thicknesses of fine, greenish-white mica rock. This quartzite is exposed mostly in thinly inhabited, wooded, upland areas where springs and dug wells adequately supply most needs. Drilled wells should yield small supplies of very good water. Due to the steep dips it is usually so far below the surface that it is not economical to drill through the overlying limestones in search of soft water from the quartzite. Overlying the Hardyston quartzite, which outcrops in Buckingham Township where it forms the main mass of Buckingham Mountain, are limestones which have been correlated with Elbrook, Conococheague, and Beekmantown limestones of other areas. The Tomstown dolomite, if present, has not been recognized. In the extreme southwestern part of the belt in which the Paleozoic rocks are exposed, a small area of Cocalico phyllite (mapped on Plate 1 as Martinsburg shale) is found. The limestones contain solution channels which are filled with water as is shown at Ingham's Springs, but all wells may not encounter similar channels. Those wells in limestone which do not encounter water-bearing openings are usually failures. It is reported that some drilled wells in this area were failures but most of them yield small supplies. None are reported to have yielded large supplies. Dug wells and springs furnish most of the water in this area. The Cocalico phyllite is not an excellent water-bearing formation but most wells in it yield small supplies of rather hard water.

In Durham Township the Hardyston quartzite is overlain by the Tomstown dolomite and the Elbrook, Conococheague, and Beekman-

town limestones in the order named. The water-bearing properties of the Tomstown are similar to the three limestones.

The limestone and older rocks are overlain by sediments of Triassic age which can be divided into three formations: the Stockton formation, the Lockatong formation, and the Brunswick shale, named in ascending order.

The Stockton formation consists of coarse, more or less disintegrated arkosic conglomerate, yellow micaceous feldspathic sandstone, reddish-brown sandstone, and soft red shale. These rocks are interbedded without regular order, and changes in lithology occur in short distances both vertically and horizontally. The shale is subordinate in amount to the coarser sediments. Although the sandy sediments are sufficiently cemented to resist rapid erosion, they are sufficiently porous that they are fairly good aquifers. In fact, the Stockton formation is probably the best ground-water horizon in the county. Very few wells fail to obtain small supplies and many wells yield 100 gallons a minute, or more. Due to the layers of shale, water is held in the sandstones under artesian pressure, and although flowing wells are not numerous, the water frequently rises close to the surface. In most places it is wise to drill to depths of 500 feet, or more.

In the southern part of the county the Baltimore gneiss. Chickies quartzite, Wissahickon formation, and the igneous intrusions associated with these three formations, are overlain by coastal plain deposits of Cretaceous and Quaternary age. Only the terrace deposits of Quaternary age are exposed on the surface, but apparently these deposits are underlain by sands and clays of Cretaceous age which may belong to the Raritan formation. In most places the terrace deposits are too thin, too thoroughly dissected, and too well drained to contain much water, and are consequently unimportant as aquifers. However, some wells in Falls and Bristol townships penetrate considerable thicknesses of coastal plain material and obtain relatively large supplies of water. Although logs of these wells were not available, conversation with the drillers indicates that the Raritan formation, which is exposed across Delaware River, is probably present but concealed beneath the Quaternary deposits.

TOWNSHIP DESCRIPTIONS

Durham, Nockamixon, Bridgeton, Tinicum, Plumstead, and Bedminster townships. The oldest rocks exposed in these six townships are the pre-Cambrian schists and igneous rocks which outcrop in the northern part of the area. These rocks are not good aquifers, but can be depended upon to yield small supplies to drilled wells. However, some wells may be failures, particularly those situated on high hills with steep sides. In general wells should not be drilled deeper than 250 feet.

The crystalline rocks are unconformably overlain by the Hardyston quartzite, which caps many of the hills and forms some of the steeper hillsides. The quartzite and the schist both outcrop in rather sparsely inhabited areas where small springs furnish adequate supplies for present needs. Future needs can be best cared for by developing springs and drilling wells. The drilled wells should produce small supplies but some of them may be failures.

The Hardyston quartzite is overlain by limestones of Cambrian and

Ordovician age. Water can usually be obtained from these limestones by drilling wells from 50 to 250 feet in depth. The yield of a well depends upon the water-bearing channels which are encountered. Wells drilled in solid limestone are usually failures.

The formations mentioned above are all covered to a greater or less extent by sediments of Triassic age. The oldest of the Triassic formations—the Stockton formation—is at the surface over such a small area that it is unimportant in these townships as a source of water.

The Stockton formation is overlain by the Lockatong formation. These rocks outcrop in the hilly portion of Durham and in Plumstead and Bedminster townships. The Lockatong formation is a better ground-water horizon in this area than it is reported to be in townships to the west. Most drilled wells in this formation yield small supplies, although wells yielding more than 25 gallons a minute are unusual. Water is encountered at depths of 30 to 300 feet. Data concerning deep drilling were not available.

The Lockatong formation is overlain by the Brunswick shale. This soft red shale is at the surface over the larger part of this group of townships. Springs, though fairly numerous, are usually small but furnish sufficient water for domestic use. Dug wells, some of which are more than 50 years old, are numerous, but in recent years most new wells are drilled rather than dug.

A well north of Point Pleasant is reported to have shot water 45 or 50 feet in the air when first drilled. (No. 1). The well flows and actuates a ram which lifts part of the water to a storage tank on the hillside. It is used to supply several cottages. The dark flaggy rock dips at an angle of 20° toward Delaware River, and the artesian pressure is evidently due to water carried in bedding planes and in the pervious sandstone. The stream flowing over the open ends of the beds may supply the water. (See analysis No. 1). The rocks exposed in the vicinity of the well are mapped as Brunswick shale but they resemble the lithology of the Stockton formation.

The yield of a well located in the valley of the Delaware at Point Pleasant exceeds that of most wells ending in the Lockatong formation. (No. 2). Due to the presence of valley fill of gravel and sand, it was necessary to case the well to a depth of 22 feet. (See analysis No. 2). The Brunswick shale yields small supplies to drilled wells (Nos. 19 to 26). Apparently the greater portion of the water is stored in bedding and joint planes because the shale is impervious. Some few sandy layers may permit the circulation of ground water.

Intrusions of diabase, chiefly in the form of dikes, are numerous. These dikes, on account of the impervious character of diabase, seriously interfere with the circulation of ground water in the intruded sedimentary rocks. The surface expression of a dike is usually a boulder-strewn ridge. Due to the presence of the boulders the difficulties of plowing the land are too great and it is left wooded while the lowlands are cleared. Because of the impervious character it is usually unwise to drill far into solid diabase. Wells in this rock usually strike small quantities of water in the first hundred feet (Nos. 27 to 29). The intrusions of diabase both as sills and dikes have baked the surrounding rocks. After baking they are much harder and frequently even more resistant to erosion that the diabase. Well

drillers report that the baked rocks adjacent to diabase intrusion are hard to drill in and that little water is obtainable.

Solebury, Buckingham, Wrightstown, Newtown, Upper and Lower Makefield townships. The oldest formation outcropping in these townships is the Baltimore gneiss. This formation outcrops in a narrow strip which crosses the southern end of Lower Makefield Township. It is in part covered by Quaternary terrace deposits. The terrace deposits are in most places so thin that they are unimportant as a source of ground water. The Baltimore gneiss is a fairly good water horizon. Drilled wells are usually successful at depths of less than 250 feet, though wells yielding more than 25 gallons a minute are not common. Failures are not numerous.

The Baltimore gneiss is overlain by the Chickies quartzite. Few wells have been drilled in this rock, but numerous small springs of very good water issue from it. The Chickies quartzite, the basal formation of the Cambrian, outcrops in a narrow belt which crosses Buckingham Township. On account of the limited areal extent of the quartzite outcrop it is unimportant as a source of ground water.

The Chickies quartzite is overlain by the Elbrook, Conococheague, and Beekmantown limestones and the Cocalico phyllite, formations of Cambrian and Ordovician age. The water-bearing properties of these limestones resemble those of the limestones outcropping in Durham Township. Ingham Spring of Dr. Richard Mattison issues from limestone (probably the Conococheague) close to its contact with the Brunswick shale 2½ miles west of New Hope. The yield is about 300 gallons a minute, and the resulting stream is dammed to form a lake of several acres. This spring was formerly the principal attraction of an amusement park. The spring is walled in on one side to form a deep basin filled with crystal clear water. Although the deepest part is reported to be 14 feet, the details of objects thrown into the pool are visible (See analysis No. 30). Drilled wells in the limestone should yield small supplies and a few wells which encounter large water-bearing solution channels may yield large supplies. Some drillers have experienced difficulty in obtaining water, indicating that, in places, the limestone is solid. The Cocalico phyllite which is mapped on Plate I as Martinsburg shale is not a good water-bearing horizon. Most wells, however, yield adequate supplies for domestic purposes.

The limestones are overlain unconformably by the Triassic sediments, of which the Stockton is the basal formation. The borough of Yardley obtains its water supply from a well drilled in 1901. (No. 31). This well flowed when drilled, but the water level is now 15 feet below the surface and the drawdown is 12 feet. The well, as shown by its log, is drilled in the Stockton formation, but the report that the tools dropped in an opening from 200 to 210 feet suggests the solution of limestone. It is possible that this well has passed through the Stockton and penetrated a solution channel in the upper part of the Cambrian and Ordovician limestone series. Because large volumes of water were obtained the driller did not drill into the underlying rock and no reports concerning its composition were made.

Log of Yardley Water & Power Co.'s well at Yardley

	Thickness Feet	Depth Feet
Surface materials	0	7
Brown sandstone	19	26
Red brown sandstone, micaceous	39	65
Brown sandstone	5	70
Brown sandstone with some calcite	10	80
Grayish material with calcite	15	95
Gray sand	30	125
Brownish gray sand	23	148
Mixture of white coarse and fine red sandstone. Some sand grains in calcite cement	52	200

The water is pumped to an 80-foot standpipe, 210,000 gallons capacity, on a hill above the borough, and distributed by gravity under an average pressure of 65 pounds per square inch. (See analysis No. 31). The borough of Newtown is supplied by the Newtown Artesian Water Company. The company obtains its water from five wells in the eastern part of the borough (Nos. 33a). The superintendent of the pumping plant reports that a fluctuation of as much as 30 feet in height of the water table occurs between the higher water levels in spring and the low levels in late summer.

In a dry hole on the property of Charles Kensey (No. 36) at Lahaska some water was encountered at 90 feet, but on drilling deeper this water was lost and no more was obtained. The driller reported striking a small pocket of gas. Another well nearby on the same property was drilled 100 feet and finished in rotten sandstone and quicksand (No. 37). It yielded 15 gallons a minute, but quickly filled up with sand. The well was deepened to 115 feet where the yield was 30 gallons a minute but it again filled in with quicksand. The well was cased with 116 feet of 6-inch casing, and deepened to 135 feet where a yield of 30 gallons a minute was obtained. The Stockton formation is an excellent ground-water horizon, and failures to obtain water are rare. Adequate domestic supplies can be developed at relatively shallow depths and industrial supplies are frequently obtainable at depths of 50 to 500 feet. Few wells yield more than 200 gallons a minute.

The Stockton formation is overlain by the Lockatong formation, which is usually considered to be a poorer water horizon. The area over which the Lockatong formation is at the surface in this group of townships is small and it is unimportant as a source of ground water.

The Lockatong formation is overlain by Brunswick shale. In most places the Brunswick shale is so thoroughly faulted and jointed that sufficient openings exist to offset the impervious character of the shale and yields of 15 to 25 gallons a minute are obtainable. It is not probable, however, that much larger yields are obtainable. Successful wells range from 40 to 250 feet in depth, and many of them are less than 100 feet deep.

Diabase intrusions occur in this area. This rock is very impervious and water is rarely found in fresh solid diabase. Wells usually obtain water from the zone of disintegrated rock and boulders resting on fresh diabase.

Northampton, Southampton, Middletown, Falls, Bensalem, and Bristol townships. The Baltimore gneiss outcrops in a long narrow

belt across Southampton, Bensalem, and Middletown townships. The water properties of this formation are discussed under the preceding group of townships.

The Baltimore gneiss is overlain by the Chickies quartzite which is a fairly good ground-water horizon. The Langhorne Spring Water Co. supplies Langhorne, Langhorne Manor, and South Langhorne boroughs with water obtained from springs issuing from these rocks. The springs are all well developed, but are allowed to run by natural stream bed to the reservoir. Evaporation losses could be prevented by inclosing the springs and piping the water to the reservoir. Wells in the quartzite are not numerous, but the data available indicate that successful wells can be drilled in this formation (Nos. 42, 43). Apparently adequate domestic supplies of very good water can be obtained at depths of 150 feet or less.

The Baltimore gneiss is overlain in other places by the Wissahickon formation, which here is an oligoclase-mica schist. It is a fairly good ground-water horizon. In most places in this area it is covered with thin veneer of terrace deposits. A number of wells are drilled through these deposits into the underlying crystalline rock (Nos. 44 to 51), but none of the records show the thickness of the unconsolidated material, nor do they state how much water was obtained before reaching the crystalline schist.

The Baltimore gneiss and associated igneous intrusions are overlain unconformably by the younger rocks. The Stockton formation is at the surface over much of Northampton and Southampton townships. Very few wells drilled in this formation are dry (Nos. 56 to 59). Industrial and municipal supplies can usually be obtained from this formation.

The Stockton formation is overlain by the Lockatong formation, which is unimportant as a source of ground water in this area.

On the south the belt of Baltimore gneiss is overlapped with coastal plain sediments, which range in age from Cretaceous to Quaternary. In most places these unconsolidated sediments are too thin to be important ground-water horizons, but in Falls Township they are thicker and a number of successful wells have been drilled (Nos. 52 to 55, and 60). The unconsolidated sands and gravels of the Coastal Plain yield large supplies of water, but the interstratified clays are quite impervious.

The Baltimore gneiss contains intrusions of gabbro which are dense and impervious and are therefore one of the poorest ground-water horizons in the area. Many wells are dry and drillers report that wells yielding more than 10 gallons a minute are rare.

Associated with gabbro are intrusions of granite which have been metamorphosed to hornblende gneiss. The water-bearing properties of these rocks resemble those of the Baltimore gneiss.

New Britain, Doylestown, Warwick, Warrington and Warminster townships. The oldest formation outcropping in New Britain, Doylestown, Warwick, Warrington, and Warminster townships is the Stockton formation. The borough of Doylestown obtains its water from a small spring-fed run, four springs, and three wells at the eastern edge of the borough. The springs are named Hellerman, Kern, Jones, and Small. A sample of water was taken from the Kern Spring. (See

analysis No. 62a.) The water from the stream, springs, and wells is collected in a small reservoir and since no effort is made to measure the yield of the various sources, it is impossible to tell how much of the 400,000 gallons a day total consumption comes from any one source. The water is chlorinated and pumped to a standpipe 30 feet in diameter and 50 feet high which holds about 250,000 gallons, from which it is distributed by gravity at pressures ranging from 30 to 90 pounds. A well east of Doylestown was originally a 26-foot dug well (No. 65). It went dry and it was decided to drill in the dry well. Water was encountered at 65 feet and it rises 25 feet. The wells in the Stockton formation are almost uniformly successful (Nos. 62a to 72, 74). Frequently successful wells are completed at depths of 100 feet or less. For larger supplies, however, it is usually necessary to drill from 200 to 500 feet.

The Lockatong formation overlying the Stockton is composed of finer and less pervious sediments. Although most of the wells in this formation yield adequate supplies for ordinary purposes, difficulty may be experienced in some places (Nos. 73, 75 to 83). In general the Lockatong formation is a less favorable ground-water horizon than the underlying Stockton formation.

Diabase intrusions are numerous in this area. One long narrow dike cuts across Doylestown, Warwick, and Warminster townships and extends southward into Montgomery County. Few wells have been drilled in diabase in this area and data concerning these wells were not obtainable.

Springfield, Haycock, Richland, Milford, East and West Rock Hill, and Hilltown townships. The oldest rocks outcropping in these seven townships are the pre-Cambrian crystalline schists, gneisses, and igneous rocks. They occur in the prolongation of South Mountain which extends into Springfield Township. The crystalline rocks usually furnish small supplies to drilled wells, though wells situated in unfavorable positions may be dry. Few wells in the schist will yield more than 25 gallons a minute, and the majority will yield from 1 to 5 gallons a minute.

The crystalline schists are unconformably overlain by the Hardyston quartzite. Few wells have been drilled in this rock, but it is probable that supplies ranging from 5 to 25 gallons a minute can be encountered at the contact of the quartzite and schist. Water obtained from the quartzite is usually low in dissolved mineral matter.

The Hardyston quartzite is overlain by limestones of Cambrian and Ordovician age, which are the same limestones that outcrop in Durham Township. The occurrence of springs yielding large volumes of water indicates that the limestones contain water-bearing solution channels. The yield of a well depends upon intersecting such channels.

The limestones are unconformably overlain by Triassic sediments. The basal Stockton formation is missing, but both the Lockatong formation and the Brunswick shale are represented. The Lockatong formation outcrops in Hilltown Township and wells drilled in it suggest that it is a reliable source of ground water, but due to the occurrence of fine-grained sediments, some wells may be failures (Nos. 84 to 91).

The Lockatong formation is overlain by the Brunswick shale. The Quakertown Water Company supplies Quakertown with water obtained

from a group of wells situated 1.5 miles north of the borough (Nos. 96a to 96h). The company has eight drilled wells, four of which are in use and four are in reserve. The driller reports that the rock near the bottom is poorly consolidated, and that the wells have a tendency to fill in. One well forms the main supply and is pumped continuously, with a Cook deep-well pump driven by a 30-horsepower motor connected with a silent chain drive (No. 96a). Three wells are pumped by air lift. The water is pumped to a brick and concrete reservoir, capacity 1,500,000 gallons, and distributed by gravity. The water is chlorinated. A sample of untreated water was collected. (See analysis No. 96a.) The borough of Perkasie is supplied by the Perkasie Water Company from springs and wells supplemented by surface water. The springs issue on Rock Hill, probably at or near the contact of the diabase with the Brunswick shale. The wells end in the Brunswick shale (Nos. 115 to 118). Although the Brunswick shale is generally considered as inferior to the Stockton formation as a source of water it is a very good aquifer. Very few wells are failures and adequate domestic supplies are frequently obtainable at depths of less than 100 feet.

Diabase intrusions are numerous in this area, the most conspicuous of which is the Haycock-Rock Hill sill. The intrusions are chiefly in the form of large sills which lie parallel to the bedding of the Brunswick shales. Wells in diabase are usually shallow because the solid rock is impervious and most of the available water is at the contact of altered and fresh rock, and also because drilling in fresh diabase is slow work and ordinarily drillers are reluctant to drill wells far below the contact zone (Nos. 122 to 124).

DRILLED WELLS IN BUCKS COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1	John Clymer	3 miles N. of Point Pleasant	200	6	Brunswick shale	Flow	50	See analysis
2	J. T. Thompson	Point Pleasant	150	6	Lockatong formation	25	25	Blue black rock; water enters near bottom; see analysis
3	Church	Wormansville	60	6	do	12	5	
4	Mrs. Billi	Pipersville	80	6	do	35	3	Water enters at 70 feet
5	Franz Burger	do	165	6	do	10	12	Water enters at 145 feet
6	Deep Run Dairymen's Asso.	2½ miles SW. of Pipersville	78	6	do	35	18	Brown and gray; water enters at 55 feet
7	William Aldridge	1 mile NE. of Plumsteadville	58	6	do	30	4	Water enters at 48 feet
8	School House	½ mile SE. of Hinkletown	60	6	do		15	
9	Mr. Moyer	Plumsteadville	80	6	do		20	Blue rock
10	Joseph Michner	Gardenville	90	6	do		2	Flows at 10 feet below surface in cellar
11	Gardenville Creamery	Gardenville	112	6	do		25	Flows 1 qt. at ±8 feet; drawdown 20 feet; recovers in 10 minutes; see analysis.
12	Whitely & Murphy	.7 mile S. of Plumsteadville	84	6	do	22	14	Blue rock; water enters at 72 feet
13	Harvey Huntsberger	1 mile SW. of Plumsteadville	70	6	do		5	
14	Samuel Gross	1 mile SW. of Plumsteadville	60	6	do		10	Near to No. 13
15	Joseph Myers	1.8 miles NW. of Danboro	97	6	do		10	
16	Margaret Harron	Danboro	160	6	do	20	6	Blue stone
17	H. Daroff	Dublin	215	6	do	4	3	See analysis
18	Titus Dressel	Dublin	80	6	do		10	
19	S. H. Diehl	1¾ miles NW. of Ottsville	40	6	Brunswick shale	20	3	Water enters at 32 feet
20	Creamery	Ottsville	220	6	do		15+	Small drawdown
21	Artemus Stewart	½ mile S. of Head Quarters	254	6	do		5	
22		1 mile S. of Erwinna	70	6	do		10	Good location in Delaware River valley
23	Charles McAtee	Tohickon	128	6	do	90	6	Water enters at 115 feet
24	M. Gulden	½ mile NW. of Kellers Church	60	6	do		20	
25	H. T. Loux	1 mile W. of Bedminsterville	104	6	do	38	6	Water enters at 95 feet

26	Edgar Stumpf	1½ miles SW. of Bedminsterville	123	6	do	35	15	Water enters at 95 feet
27	Harry Arnold	½ mile N. of Danboro	58	6	Diabase	30	13	Water enters at 45 feet
28	Mr. Dutter	½ mile NE. of Fountainville	57	6	do	38	6	Water enters at 45 feet
29	Mrs. Dorothy Gentert	do	41	6	do	25	6	Water enters at 31 feet
31	Borough of Yardley	Yardley	210	8	Stockton formation	15	180	Drawdown 12 feet; see analysis
32	Gilbert G. Cadwallader	do	101	6	do	11	1.5	Water enters at 56 feet
33a	Artesian Water Co. No. 1	Newtown	112	6	do	----------	120	
33b	do No. 2	do	112	6	do	----------	349	
33c	do No. 3	do	180±	8	do	40	140	See analysis
33d	do No. 4	do	220	8	do	45	140	See analysis
33e	do No. 5	do	340	12	do	----------	220	
34	George Esche	do	160	6	do	----------	15	Sandstone
35	William Carver	1 mile S. of Carversville	140	6	do	----------	20	
36	Charles Kensey	Lahaska	115	6	do	----------	Dry	
37	----------	do	135	6	do	----------	30	See text
38	Walter Wiley	Mechanicsville	115	6	do	----------	20	Red shale
39	John Wipf	Spring Valley	60	6	do	38	15	Water enters at 50 feet
40	Isaac Ryan	Forrestville	80	6	Brunswick shale	6	25+	Drilled in a dug well
41	Cyrus Quinn	Pineville	45	6	do	14	15	Water enters at 37 feet
42	N. J. Bryant	Near Langhorne Station	170	6	Chickies quartzite	70	17	
43	Neshaminy Falls	Neshaminy Falls	40-100	6	do	----------	5	Numerous wells
44	H. T. Michell Seed Co.	Andalusia	257	8	Wissahickon formation	10	12	
45	John Hagen	Cornwells	62	6	do	20	15	
46	Mrs. J. Drexel	do	431	6	do	80	7	Drawdown 40 feet
47	do	do	50	6	do	20	12	Drawdown 10 feet
48	Charles E. Biddle	Cornwells	337	8	Wissahickon formation	245	3	
49	St. Francis Indus. School	Eddington	400	6	do	----------	100	
50	----------	----------	500	6	do	----------	100	
51	Miss E. M. Bartine	Bensalem	100	6	do	20	7	
52	Mrs. J. Drexel	Cornwells	35	6	Quaternary	----------	Dry	
53	Rohn & Hass	Bristol	96	8	do	22	100	
54	Joseph H. Grundy	do	150	6	do	8	26	Drawdown 37 feet
55	Pennsylvania R. R.	Morrisville	100	8	do	12½	86	
56	Albert Bartlett	Richborough	115	6	Stockton formation	----------	7	
57	----------	Churchville	75-115	6	do	----------	8-15	15 Wells
58	----------	Southampton	74-275	6	do	----------	10-30	Red shale. 40 wells
59	Sunshine Home	Davisville	120	6	do	----------	30	Red shale
60	Arsenal Powder Plant	Tulleytown	160	6	Quaternary	----------	50	
61	Clayton Bergy	¾ mile SW. of Fountainville	80	6	Lockatong formation	----------	2	Later went dry
62b	Doylestown borough Well No. 1	Doylestown	187	----------	Stockton formation	----------	----------	Pumped with air lift; see analysis
62c	do Well No. 2	do	194	----------	do	----------	----------	do
62d	do Well No. 3	do	620	----------	do	----------	----------	do
63	Harry Haldeman	New Britain	75-85	6	do	----------	25	Red sandstone and shale. 6 wells
64	John Andre	South of Doylestown	168	6	do	40	80	Drawdown 60 feet
65	I. Harnish	1½ miles E. of Doylestown	91	6	do	40	14	See text

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
66	Earl Colby	Bushington	115	6	do	60	10	Water enters at 90 feet; small drawdown
67a	Well No. 1	do	100	6	do	----	1	
67b	Well No. 2	do	65	6	do	----	10	
67c	Well No. 3	do	65	6	do	----	10	
68	Miss A. B. Hanna	do	151	6	do	110	18	Water enters at 135 feet
69	Elmer Austin	Near Bushington	75	6	do	50	8	Water enters at 60 feet
70	Samuel McKinstery	Newville	120	6	do	----	5	Brownstone
71	Dr. Wasserman	do	300	6	do	70	8	
72	Ed. Behrman	Warrington	76	6	do	----	8	
73	Jacob Shelly	½ mile SE. of Griers Corner	80	6	Lockatong formation	----	10	
74	Howard Twinning	Johnsville	135	6	Stockton formation	----	20	
75	J. Carroll Molley	Bridge Valley	125	6	Lockatong formation	18	60	
76	Robert Hendricks	do	100	6	do	40	10	
77	John L. Craig	1½ miles S. of Doylestown	425	6	do	----	3	Brownstone and black shale
78	do	do	300	6	do	----	½	
79	Bucks County Home	2½ miles S. of Doylestown	245	6	do	----	1	
80	do	do	230	----	do	----	----	
81	Smith & Saffran	Newville	60	6	do	23	14	Water enters at 45 feet
82	----	100 feet from No. 63	50	6	do	24	10	Water enters at 40 feet
83	Synagogue, Street Road	1 mile NW. of Warrington	68	6	do	45	7	Water enters at 52 feet
84	Meeting House	1 mile E. of Blooming Glen	115	6	do	80	8	Water enters at 100 feet
85	Joseph Kulp	Blooming Glen	120	6	do	----	20	
86	Catholic Church	½ mile S. of Mt. Pleasant	100	6	do	----	10	
87	----	Leidystown	70	6	do	----	20	Fine-grained blue rock
88	Samuel Lengle	1¼ miles N. of Line Lexington	80	6	do	----	20	
89	----	Fairhill	140	6	do	----	10	Hard blue rock throughout entire depth
90	Mennonite Church	Line Lexington	50	6	do	----	10	
91	----	do	75	6	do	----	10	
92	Catholic Church	Haycock	70	6	Brunswick shale	----	20	
93	M. M. Kamer	Zion Hill	198	6	do	----	----	Practically dry
94	Wemhach	do	65	6	do	----	15	
95	David Kemmerer	Steinsberg	140	6	do	----	8	
96a	Quakertown Water Co. Well No. 1	1½ miles N. of Quakertown	367	8	do	8	250	
96b-96h	Wells Nos. 2 to 8	do	150±	8	Brunswick shale	8	100	
97	Garage	Richlandtown	90	6	do	----	20	
98	Joseph Thomas	Quakertown	127	6	do	----	30	
99	Panco Cigar Co.	do	75	6	do	----	60	Some H_2S

100	Quakertown Power House	do	108	10	do		225	
101	Quakertown Stove Works	do	125	6	do		25+	Not used on account of H_2S
102	Linford Foulks	do	175	6	do		2	
103	Herman Sadler	do	56	6	do		10	
104	Henry Kinsey	do	112	6	do		15	Large drawdown
105	J. W. Shaw	do	18	96	do		5	Goes dry
106	Mr. Rosenberger	Milford Square	50	6	do		10+	
107	Frank Mack	do	67	6	do		10	
108		Spinnerstown	50-100	6	do		10+	15 wells
109	Creamery	do	70±	6	do		20	
110	Mr. Rader	Geryville	80	6	do		15	
111		Trumbauersville	100±	6	do		10±	Numerous wells
112	Triangle Service Station	1 mile NW. of Perkasie	50	6	do		20	Flows in wet weather
113a	Well No. 1	½ mile NW. of Perkasie	75	6	do		10	
113b	No. 2	do	82	6	do		10	
113c	No. 3	do	83	6	do		10	
114	H. Benner	Perkasie	112	6	do		15	
115	Perkasie Water Co. Well No. 1	do	141	8	do		78	City supply
116	do Well No. 2	do	100	8	do		60	do
117	do No. 3	do	221	8	do		70	do
118	do No. 4	do	200		do		80	do
119	William Derstine	Derstines	83	6	do		15	
120	Rock Hill Mennonite Church	1 mile NE. of Telford	108	6	do		15	
121	Reading Co.	Telford	300	6	do		300	Locomotive use
122	School House	Rocky Ridge	40±	6	Diabase		5	
123	West Rock Hill School	2½ miles S. of Quakertown	22	6	do	10	10	Did not penetrate solid diabase; see analysis
124	Rocky Ridge Hotel	3 miles S. of Quakertown	50	6			6	

CHESTER COUNTY

GENERAL CONDITIONS

Chester County, which has an area of 777 square miles, is one of the southern tier of counties and adjoins both Maryland and Delaware. The total population according to the United States census of 1930 was 126,629, including Coatesville, which has 14,582 inhabitants, and West Chester, the county seat, which has 12,325 inhabitants. The average number of inhabitants per square mile is 163, or approximately three-fourths of the average for the State. Chester Valley is the most densely populated area in the county, particularly in the vicinity of Coatesville, which is a highly developed industrial center. The vicinity of West Chester, is also thickly settled, but not so highly industrialized as the Coatesville area. The remainder of the county is distinctly rural, and in some parts, such as the "Barrens" along the Maryland State line, very sparsely inhabited. The same census reports that there are 4760 farms in the county.

Coatesville and West Chester have surface water supplies. A number of smaller towns, including Avondale, Atglen, Honeybrook, Malvern, Oxford, Parkesburg, and Westgrove, use ground water, and the rural population uses ground water almost exclusively. The mushroom industry, which is centered in Chester County, particularly in the vicinity of West Chester, Avondale, and Kennett Square, requires large quantities of water, most of which is obtained from wells.

Springs are still a favorite source of water, both for towns and farms. Most of them yield only a few gallons of water a minute, but they are generally perennial or fail only in exceptional periods of drought. Many of the springs are not close to the farmhouses which they supply, their yield is insufficient to operate hydraulic rams, and consequently the water must be either carried or pumped. Most new houses obtain their supplies from wells rather than springs. Many farms obtain their supplies from dug wells, some of which have been in use for more than a hundred years, but drilled wells are becoming more numerous.

GEOLOGY OF CHESTER COUNTY

The following geologic column is inserted at this point for the convenience of the users of this section of the report.

Geologic column in Chester County[1]

SEDIMENTARY ROCKS

Age	Name and description	Thickness Feet	Water-bearing properties
Quaternary (Pleistocene)	Talbot formation. Gravel and sand on terraces 60 to 40 feet above sea level.	0-20	These beds are unimportant as sources of ground water on account of thinness and small areal extent.
	Sunderland formation. Gravel and sand on terraces 180 to 100 feet above sea level.	0-20	
	Brandywine gravel. Gravel no terrace 220 feet above sea level.	0-10	
Tertiary (?) (Pliocene ?)	Bryn Mawr gravel. Gravel on uplands 400 to 300 feet above sea level.	0-20	Unimportant as a source ot ground water. Shallow wells might be successful in the larger areas underlain by these gravels.
Triassic	Brunswick shale. Chiefly red shale with subordinate amounts of sandstone and conglomerate.	5,000±	The Brunswick shale is usually a fair water-bearing formation. The shales are impervious but joint and bedding planes usually contain some water and wells are rarely failures. They usually yield supplies adequate for domestic purposes.
	Lockatong formation. Dark, hard shale, fine-grained sandstone and flagstones.	0-1,000	The poorest ground-water horizon in the Triassic group. Domestic supplies are usually available at depths of not more than 250 feet.
	Stockton formation. Gray sandstone, arkose, conglomerate, and red shale.	4,500±	Wells usually successful. Some may yield as much as 20 gallons per minute.
	Unconformity		
Ordovician	Cocalico shale. Bluish black to dark gray fissile shale; purple and green shale.	1,000±	The Cocalico shale yields small supplies of rather hard water.
	Conestoga limestone. Thin bedded blue limestone, gray granular limestone with slaty partings, coarse limestone conglomerate at base.	1,000±	Except that the purer limestones contain more large solution channels these limestones and dolomites are similar in water-bearing properties.
	Beekmantown limestone. Pure light gray limestone, laminated magnesian limestone, gray dolomite, and black chert.	2,000±	
	Unconformity		
Upper Cambrian	Conococheague limestone. Light blue limestone banded with siliceous impurities, dolomite, and fine-grain white marble.	1,000±	
Upper and Middle Cambrian	Elbrook limestone. Thin-bedded to shaly, fine-grained, white to cream-colored marble and limestone with sericitie partings.	300	The rocks are dense and impervious but fracture, joint, bedding, and fault planes and solution channels may contain water and wells which encounter such opening are successful.

[1] This columnar section was compiled from the U. S. Geol. Survey Geol. Atlas, Philadelphia folio, No. 162, U. S. Geol. Survey Bulletin 799, Lancaster Quadrangle (Pennsylvania Topo. and Geol. Survey) No. 168 and U. S. Geol. Survey Atlas Coatesville-West Chester folio, No. 223.

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Lower Cambrian	Ledger dolomite. Light gray granular dolomite.	600±	
	Kinzers formation. Dark shale (in part altered to schist) below, and banded blue limestone and white spotted marble above.	200±	Same as limestones above. Wells which intersect solution channels may yield large supplies.
	Vintage dolomite. Dark blue knotty dolomite with impure marble at base.	300±	
	Antietam quartzite. Gray laminated quartzite.	150±	Yields small supplies of very good water.
	Harpers phyllite. (In part altered to schist) Light gray phyllite and dark banded slate; where altered to schist laminated quartzite and quartzose schist.	1,000±	Yields small supplies of fairly good water.
	Chickies quartzite. With Hellam conglomerate member at base. Thin bedded to massive quartzite and quartz schist, thin mica schist, and quartz conglomerate.	600±	Small supplies of very good water.
Algonkian (Glenarm series)	Peters Creek schist. Green, fine laminated, quartzitic, muscovite-chlorite schist.	2,000±	A fairly good water-bearing horizon. Most wells yield small supplies.
	Wissahickon formation. In northern part, albite-chlorite schist facies with some muscovite schist; in the south, oligoclase-mica schist facies, in part muscovite gneiss and in part biotite gneiss.	6,000±	A fairly good water-bearing horizon. Most wells yield small supplies but some wells yield 100 or more gallons a minute.
	Cockeysville marble. White to gray fine-grain marble.	200	Water found only in fracture, joint, and fault planes and in solution channels. Some wells yield large supplies, others are failures.
	Setters formation. Buff quartzite, gray quartz-biotite-feldspar gneiss.	1,000±	Small supplies of very good water.
Archean	Baltimore gneiss. Biotite or hornblende gneiss, in part massive with little banding, in part graphite-bearing muscovite-biotite gneiss.	?	Most wells are successful but yield small supplies. A few wells yield larger supplies.
	IGNEOUS ROCKS		
Triassic	Diabase. Granular to fine-grained trap in dikes.	?	Few wells have been drilled in diabase.
Pre-Cambrian	Pegmatite. Coarsely crystalline feldspar, quartz, and mica.	?	
	Serpentine. Altered pyroxenites and peridotites.	?	Wells in these rocks yield small supplies of rather highly mineralized water.
	Gabbro. Coarse-grained igneous rock; feldspar, mica, and hornblende with accessory minerals.		A poor water horizon. A few strong wells are reported but many wells yield less than 3 gpm.
	Granite, granite gneiss, quartz diorite, quartz monzonite, and anorthosite.	?	Poor water-bearing rocks. Yield small supplies.

The Baltimore gneiss is found in considerable areas both north and south of Chester Valley. In this county it contains, in places, considerable amounts of graphite. While this gneiss does not usually yield large supplies of water, a few wells in it are reported to obtain fairly large supplies. The Franklin limestone, which is mapped with the Baltimore gneiss on Plate I, occurs in small patches, chiefly in the northern part of the county. The Setters formation occurs in several areas in the southern part of the county. While this rock in its typical development is a micaceous quartzite, in many places it is a mica schist or mica gneiss. In places the quartzite contains large quantities of garnet and tourmaline. Where joints are well developed the Setters quartzite should yield fairly large supplies of water low in dissolved solids, but where it is dense and without joints it will yield but little water.

The Cockeysville marble underlies three fertile valleys, one in the vicinity of Doe Run, another around Avondale and extending to Kennett Square, and a third south of Landenberg. There are also other small areas of this rock. Natural outcrops of the marble are rare, but it is exposed in quarries and cuts. Most of the quarries are abandoned and many of them are filled with water, most of which is ground water. The water conditions in the Cockeysville marble are always uncertain. Thus one well may yield 100 gallons a minute and another only 5 gallons.

The Wissahickon formation in this county is a schist, the gneissic character, so well developed in Delaware County, being subordinate. This formation is at the surface over a large area. In most places it is deeply covered with soil, which, in many places, is full of glittering flakes of mica. This rock is somewhat more favorable as a source of water than the Baltimore gneiss, and while failures are not unknown, most wells obtain small supplies. Wells usually yield from 2 to 25 gallons per minute, but yields up to 100 gallons a minute are reported. In some areas water from this formation is reported to be hard but in most areas the water is soft. Apparently the hard water is due to the leaching of disintegrating lime-soda feldspars.

The Peters Creek schist, which overlies the Wissahickon formation, consists of a gray to green schistose quartzite interbedded with muscovite-chlorite schist. In places the Wissahickon formation seems to grade into the Peters Creek formation. Exposures of relatively fresh rock occur along the new State highway south of Coatesville. The rock breaks into thin plates which have a pearly luster. Wells in this formation are usually small producers, but failures are common.

The Chester Valley is underlain by limestones and shales of Cambrian and Ordovician age. The hills on the north side between the valley and the uplands underlain by Baltimore gneiss are formed by the resistant Lower Cambrian rocks. The oldest Cambrian formation in these hills is the Chickies quartzite which is composed of thin bedded to massive quartzite and quartz schist, thin mica schist, and conglomerate with the massive Hellam conglomerate member at the base. This quartzite is a fairly good ground-water horizon and drilled wells usually obtain an adequate supply of water low in total dissolved solids. The total thickness of this formation is approximately 700 feet. The Chickies quartzite is overlain by the Harpers schist which is about 1000 feet thick. These rocks are dense sandy schists and quartzites which

are not very favorable aquifers. Drillers, however, report that they obtain small supplies of ground water in most wells that are over 75 feet deep. Most of the water is obtained from bedding, schistosity, and joint planes and from fractures. Few wells yield over 10 gallons per minute. The Harpers phyllite is overlain in a few small areas by the Antietam sandstone but this formation is unimportant as a source of ground water. It is mapped with the underlying Harpers schist on Plate I. The Chickies quartzite and Harpers schist dip steeply beneath the limestones of the valley. The formations exposed in the valley are the Vintage dolomite, Kinzers formation, Ledger dolomite, Elbrook limestone, and Conestoga limestone. West of Coatesville, the Conestoga overlaps the older formations and is at the surface over the entire width of the valley. The water-bearing properties of these calcareous formations are discussed under Valley and Sadsbury townships.

The Stockton formation, like the other Triassic formations, forms an open rolling country which contrasts sharply with the rugged region to the south underlain by crystalline rocks. This formation is probably the best water-bearing horizon of the Triassic rocks. The areal distribution of the Lockatong formation in this county is confined to a narrow, tapering belt that dies out before crossing the county. The ridge-forming character is less conspicuous here than in Montgomery County. The Brunswick formation is represented by conglomerate in the northern part of the county. On account of the coarser sediments this rock should yield somewhat larger supplies than the normal Brunswick shale.

Igneous rocks of pre-Cambrian age range from granite to very basic rocks, largely altered to serpentine. Diabase dikes of Triassic age occur in the northern part of the county, and while they exert some influence on the circulation of ground water, this influence is of less importance in the crystalline rocks than in more porous and less metamorphosed sedimentary rocks. Like the other crystalline rocks of the Piedmont Plateau, the granite and related rocks weather to deep soils which are usually cultivated. Outcrops are scarce and the best exposures are found in railroad and highway cuts and in quarries. The fresh granite is a dense rock composed entirely of closely locked grains without sufficient porosity to permit the movement of ground water in large volumes. The granite, in most places, has two systems of vertical joints and one of horizontal joints.

Chester County is divided into 57 townships, 24 boroughs, and one city—Coatesville. The ground-water conditions of each township and the included boroughs, are briefly described and are shown by the well records given in the table at the end of the township descriptions.

TOWNSHIP DESCRIPTIONS

Schuylkill Township. Schuylkill Township includes the borough of Phoenixville, which obtains its water from Schuylkill River. The Stockton and Lockatong formations are at the surface over the greater part of the township. Judging by the wells in Montgomery County, the Stockton formation is probably the better source of water and will yield larger supplies. The Phoenixville Iron Co. obtains its drinking water from a drilled well in the Stockton formation. Two wells across the river, in Montgomery County, are 86 feet and 96 feet deep, respec-

tively, and each yields approximately 6 gallons a minute. The Lockatong formation is denser and its yields are usually smaller. The Lower Cambrian Harpers phyllite and Chickies quartzite (including its basal Hellam conglomerate member) make the ridge which forms the southern boundary of the township. These formations should yield small supplies. In general the quartzite should yield larger and better supplies than the Harpers formation. Quartz diorite also outcrops in the township.

Tredyffrin Township. The populous towns along the Pennsylvania Railroad in Tredyffrin Township are supplied with surface water by the Springfield Consolidated Water Company. The Wissahickon formation, which forms the ridge south of the Chester Valley, is the oldest formation outcropping in the township. A number of wells have been drilled in this rock in recent years. The two wells (Nos. 1 and 2) listed in the table are typical except that many successful wells are shallower. The ridge on the north side of the Chester Valley is underlain by the Chickies quartzite including its basal Hellam conglomerate member, and the Harpers phyllite. Wells are not numerous in these rocks, but in most places they will yield small supplies of good water low in total dissolved solids. Chester Valley is underlain by limestone and associated shale. Successful wells have been drilled in the valley but there are also a number of dry holes. Some years ago a number of holes were drilled for quarrying operations at a quarry of Samuel Given near Howellville, and very little water was encountered. (See Nos. 3a and 3b.) A few patches of terrace deposits occur in this township but they are too thin to contain a large volume of ground water.

Easttown Township. In Easttown Township the Baltimore gneiss is at the surface over a small area and is a source of small supplies. The Wissahickon formation which outcrops over a larger area, also yields small supplies. (See Nos. 4a, 4b, and 5.) Gabbro, which is the surface formation over much of the township, is a somewhat less reliable source of water.

Williston Township. The rocks outcropping in Williston Township are the Baltimore gneiss, with intrusions of gabbro, and the Wissahickon formation, which has been intruded by basic rocks now largely altered to serpentine and related rocks. The Baltimore gneiss can be depended upon for small supplies (Nos. 5a and 5b). However, efforts to develop large supplies at 5a were not successful. All the water in this 211 foot well was obtained in the first 50 feet. Well No. 5b is typical of the kind of wells that may be expected in the Baltimore gneiss in this area. Although the gabbro is ordinarily a poor water-bearing horizon some large supplies (No. 5c) can be obtained by drilling wells in this rock. An 8-foot dug well, at the site of existing well, with an overflow pipe 4 feet below the surface was in use for many years. About 1925 the yield of this well decreased and the 100-foot well was drilled. Water rose to the surface. On a pumping test of 7 hours this well yielded 125 gpm with a drawdown of only 12 feet. A 1¼-inch pipe was inserted in the casing six feet below the surface and the pipe flowed full until November, 1930, when due to the prolonged drought the water level dropped below the pipe. A siphon of 1¾-inch pipe with its end 20 feet below the surface was installed and no further difficulty had been experienced. The ground water comes to the

surface at this point, apparently, on account of the damming action of the Baltimore gneiss. The contact of the gabbro and the gneiss is but a few yards from the well. The contact is marked by several springs.

The hamlet of Duffryn Mawr is on the schist of the Wissahickon formation. It is supplied with surface water by the Springfield Consolidated Water Co. but there are also successful wells (Nos. 6 to 11) in the schist in this vicinity and at Malvern and Frazer in East Whiteland Township. The borough of Malvern has a municipal system of waterworks which obtains its supply from a dug well 20 feet in diameter and 18 feet deep. This well, which is also in the Wissahickon formation, yields about 35 gallons a minute.

East Pikeland Township. The Baltimore gneiss outcrops in East Pikeland Township with intrusions of quartz diorite, except in the northern part, where the older rocks are overlain by the Stockton and Lockatong formations and the Brunswick shale, of Triassic age. The Lockatong formation is notably the poorest of these three formations as a source of water.

Charlestown Township. The Baltimore gneiss, which outcrops in the northern part of Charlestown Township, and the quartz diorite which underlies the greater part of the township, usually yield small supplies. The Lower Cambrian formations (Chickies quartzite and Harpers schist) yield small supplies of relatively soft water. The Elbrook limestone (Middle and Upper Cambrian) outcrops in the southern part of the township and is an uncertain ground-water horizon. The most favorable water horizon in the township is the Stockton formation, which consists largely of red sandstone and shale.

East Whiteland and West Whiteland townships. Most of East Whiteland and West Whiteland townships is in Chester Valley, which is underlain by limestone. The water-bearing properties of these rocks are discussed under Valley and Sadsbury townships. The Wissahickon formation makes the ridge to the south of the valley and the Lower Cambrian quartzite the ridge on the north side. This crystalline rock is a fairly good ground-water horizon. The well of Rev. Patrick Dwyer, (No. 10), and the well of the Pennsylvania Railroad (No. 11), at Frazer, are examples of wells in the Wissahickon formation.

East Goshen and West Goshen townships. West Goshen Township includes West Chester, the seat of Chester County. The Baltimore gneiss, with some intruded gabbro, is at the surface over a large part of both East and West Goshen townships, and supplies a number of wells (See Nos. 12 to 16 and 18e to 24). The Wissahickon formation is also an important source of ground water (See Nos. 17 and 18a to 18d.) In the vicinity of West Chester five drilled wells in the Wissahickon formation, from 60 to 70 feet deep, yield about 10 gallons a minute each. At Greenhill, four wells with relatively large yields were drilled in this formation for Ed. H. Jacob (Nos. 18a to 18d). These four wells yield more water than most wells in the Wissahickon formation. Mr. Jacob has a number of wells at his mushroom plant near West Chester that are drilled into gabbro. Some of these yield much larger supplies than are usually obtained from this rock. Within a mile of these good wells, four other wells (Nos. 20 to 22a), were drilled, ranging from 56 to 87 feet in depth and from 6 to 20 gallons

a minute in yield. Although the writer has no data on failures to obtain water in this area, it is improbable that wells will be uniformly successful. Serpentine occurs in small areas but is not important as a source of water.

Westtown, Thornbury, and Birmingham townships. Baltimore gneiss is at the surface over most of Westtown Township and supplies a number of wells (See Nos. 25 to 28). The Wissahickon formation is also an important source of water in this township. The Westtown Boarding School has seven drilled wells (No. 29) ranging from 40 to 200 feet in depth. The water rises within 6 feet of the surface, and the wells are pumped simultaneously by compressed air, yielding in all 200 gallons a minute. An older well, 200 feet deep and close to the buildings, was drilled through the schist into serpentine, but was abandoned because the water contains larger amounts of magnesium. Both gabbro and serpentine outcrop in the township, but are not important sources of water. The serpentine is confined to a few small areas which had best be avoided if possible when locating a well site.

The conditions in Thornbury and Birmingham Townships are similar to those in Westtown Township (See wells Nos. 31 and 32).

East Coventry and East Vincent townships. Almost all of East Coventry and East Vincent townships are underlain by Triassic rocks, consisting chiefly of red sandstone and shale. The crystalline rocks outcrop in only a small area in the southern part of East Vincent Township and are of little importance as sources of water. The Stockton formation, which is the oldest Triassic formation outcropping in the area, yields fairly large supplies of rather hard water. The Lockatong formation, which occupies a narrow belt of upland country, is rarely as good a source of water as the underlying Stockton formation. The Brunswick formation, which overlies the Lockatong, is at the surface over most of the area. It is usually a fair water horizon. Wells Nos. 33 to 36, listed in the table, are typical of the smaller wells in this formation. Larger yields can frequently be obtained. Spring City obtains its water from Schuylkill River.

North Coventry Township. All of North Coventry Township is underlain by either shale or conglomerate of the Brunswick formation. At Cedarville a number of successful wells have been drilled into this formation (See Nos. 37 to 41). The well of Walter Bell (No. 37) was drilled through 90 feet of micaceous red sandstone and 35 feet of red shale, and was cased to a depth of 100 feet. The well of Ruben Updegrove (No. 41) is in conglomerate. The Kline Realty Co. has had 15 wells, or more, drilled along the highway leading southward from Pottstown. These wells average about 100 feet in depth and about 12 gallons a minute in yield.

South Coventry Township. Crystalline rocks outcrop in the southern part of South Coventry Township, including the graphitic facies of the Baltimore gneiss, and quartz monzonite, and gabbro. The Stockton formation supplies a number of wells (See Nos. 42 to 45). The Lockatong formation outcrops in a narrow belt and disappears before crossing the western edge of the township. The Brunswick formation outcrops in the northern part of the township. The well records for North Coventry Township are also applicable here. Diabase outcrops

in the western part of the township. Small supplies can usually be obtained from this rock.

West Vincent and West Pikeland townships. Crystalline rock outcrops in all parts of West Vincent and West Pikeland townships, except in the northeastern part of the former, where red sandstone and shale of the Stockton formation are at the surface. The crystalline rocks consist of Baltimore gneiss, with outcrops of gabbro, quartz monzonite, quartz diorite, and serpentine. Several patches of Franklin limestone are exposed in this area. The well of J. Harvey Emery, at Chester Springs (No. 51), is rather typical of drilled wells in the gneiss.

Warwick Township. The geology of Warwick Township is complicated, and a large number of formations ranging in age from pre-Cambrian to Triassic outcrop in the township. The Lower Cambrian formations, as well as the pre-Cambrian, are thoroughly metamorphosed. The rocks in this area have been intruded by large amounts of Triassic diabase, but except for some baking of shales immediately adjacent, the intrusions have not altered the rocks into which they were intruded. The Triassic rocks are better water horizons. The Stockton formation yields small supplies at relatively shallow depths in South Coventry Township to the east. The Brunswick formation is at the surface in the northern part of the township. The well of Parker Noble (No. 46) is typical of many wells in the Brunswick formation but wells having smaller yields are common.

East Nantmeal and *West Nantmeal townships.* In both East and West Nantmeal townships crystalline rocks of pre-Cambrian and Cambrian age are at the surface over a large area. The Baltimore gneiss and the intruded quartz monzonite and anorthosite supply water to wells (See Nos. 47 and 48). No wells have been drilled in the anorthosite in either of these townships, but a well drilled into it in Honeybrook Township, which is 60 feet deep and yields about 5 gallons per minute, indicates that the anorthosite, like most of the other crystalline rocks, will yield small supplies. The well at the Dolfinger Creamery in Elverson (No. 49) and the well of Henry Zook near by (No. 50) apparently obtain their water from the Chickies quartzite.

Wallace, East Brandywine, and West Brandywine townships. The Baltimore gneiss occurs at the surface over much of these townships. The well on the Brandywine Fruit Farm (No. 52) is a typical well. The igneous rocks that have been intruded into the gneiss are quartz monzonite, anorthosite, and gabbro. Faulting along the southern edge of the anorthosite intrusion and north of the Chester Valley, combined with subsequent erosion, has exposed several areas of Cambrian quartzite. (See well No. 53).

Uwchlan and Upper Uwchlan townships. With the exception of the southern part of Uwchlan Township, where the sandy Lower Cambrian rocks outcrop, Uwchlan and Upper Uwchlan townships are underlain by crystalline rocks. The Cambrian rocks are not completely recrystallized but are strongly altered. The Baltimore gneiss outcrops in both townships, but is more widespread in Upper Uwchlan. (See wells Nos. 54 and 55). Quartz monzonite and gabbro also out-

crop in the area and in most places will yield small supplies. The Lower Cambrian sandy formations which outcrop in the southern part of Uwchlan Township, usually yield small supplies, and in some places where they are well jointed they may yield larger supplies. However, these rocks outcrop in a thinly populated area where few wells are drilled.

Caln and East Caln townships. The larger part of the area covered by Caln and East Caln townships is in the Chester Valley, but each township extends a short distance north and south of the valley. The Baltimore gneiss outcrops on the north side of the valley. (See wells Nos. 56 and 58.) The Wissahickon formation makes the hill on the south side of the valley. (See well No. 57.) South of Thornsdale several wells ending in this formation range from 40 to 60 feet in depth and yield about 5 gallons a minute each. The Lower Cambrian quartzite formations outcrop in the ridge on the north side of the valley. The valley itself is underlain by limestone. A number of sink holes north of Caln show that solution channels occur in the underlying limestone. Wells Nos. 60 to 62 end in the Conestoga limestone (Ordovician), in which sink holes are less numerous.

East and West Bradford townships. Both East and West Bradford townships contain only pre-Cambrian crystalline rocks except a small area of Conestoga limestone at the north end of East Bradford Township. Well No. 63 is probably in the Baltimore gneiss and Nos. 64 and 65 are in the Wissahickon formation. The well of Paul Pearson, Harmony Hill, (No. 66), is in the Peters Creek schist, which lies in a syncline in the Wissahickon formation and outcrops in a belt several miles wide. Gabbro outcrops in large areas in East Bradford Township, and serpentine occurs in a few isolated patches.

Newlin, Pocopson, and Pennsbury townships. The area included in these townships is everywhere underlain by crystalline rocks. The well at the Chadds Ford Consolidated School (No. 67) is supplied by the Baltimore gneiss but is probably a better well than most of those drilled in the gneiss. The Setters formation, which is at the surface in a small area in Pennsbury Township, should yield small supplies of good water. The Cockeysville marble outcrops in an elongated strip in Pennsbury Township. No well data are at hand for this area, but wells drilled here should obtain results similar to those obtained in Kennett Township. The Wissahickon formation is by far the most widespread one in the area. (See wells Nos. 68, 69, 71, 72.) The Peters Creek schist outcrops over a large area where relatively few wells have been drilled. However, in most places the water-bearing properties of this schist resemble those of the underlying Wissahickon formation, and wells in it should yield small supplies at moderate depths. Gabbro is found in small areas. Serpentine outcrops in both townships.

Honeybrook Township. Quartz monzonite is at the surface over a large area in Honeybrook Township. The well of Mr. Grube (No. 73), near the spring which supplies Honeybrook, is probably in the Baltimore gneiss, but several faults cut the rocks in the vicinity, making it difficult to tell the formation from which the water is obtained. The gneiss has been intruded by igneous rocks, such as quartz monzonite,

anorthosite, and gabbro as well as basic rocks now altered to serpentine. A number of wells have been drilled in the quartz monzonite. (See Nos. 74 and 75.) The well of Samuel Crouse (No. 76), at Cupola, is drilled in anorthosite. There are no data concerning drilled wells in gabbro in this township, but according to results obtained elsewhere in Chester County small yields should generally be obtained although some wells may be failures. In Welsh Ridge, which forms the northwestern boundary of the township, are exposed the Cambrian formations—Chickies quartzite, with its basal Hellam conglomerate member, and the Harpers phyllite. The Chickies quartzite is doubtless the source of the springs which supply Honeybrook. The water from three springs flows into a concrete basin and thence by pipeline to Honeybrook, 1½ miles to the southeast. About half way to the town is a storage reservoir. This water, like most of that derived from the Chickies quartzite, is very low in total dissolved solids (See analysis 213). In a faulted zone on the north flank of Barren Ridge, in the southern part of the township, Lower Cambrian rocks also occur.

West Caln Township. The geology of West Caln Township is very complicated due to the folding and faulting of the rocks on Barren Ridge. The Baltimore gneiss outcrops in a narrow strip in the vicinity of Wagontown as well as in the southern part of the township. (See wells Nos. 77 to 79.) Gabbro is at the surface over a large area in this township but few wells have been drilled in it. The Cambrian formations not only include the Chickies quartzite and Harpers phyllite, but also the Vintage dolomite. The drilled well of Martin Miller (No. 80) is in the Chickies quartzite. Wells in the quartzite and in its basal Hellam conglomerate member should in general be similar. There is no information at hand on wells in the Harpers phyllite, but small supplies should be obtained from wells drilled into it. The Vintage dolomite will yield large or small supplies depending on the solution channels encountered by the wells. A well drilled into this rock west of Compass is 90 feet deep and yields 40 gallons per minute.

Valley Township. Although part of Valley Township is in Chester Valley, most of it lies in uplands north of the valley. The city of Coatesville, situated in this township, uses Rock Run as a water supply. The Baltimore gneiss outcrops in the area with intrusions of gabbro. (See well No. 81.) The Wissahickon formation is exposed in the ridge south of the valley. (See wells Nos. 82 and 83.)

The Lower Cambrian formations form the rim of the ridge north of the valley. The basal Hellam conglomerate member of the Chickies quartzite rests directly upon the Baltimore gneiss. The well of William Heffner (No. 84) on the Lincoln Highway just west of Coatesville is in Chickies quartzite. There are several wells in the vicinity drilled into this formation which have the same depth and yield. The well at Brown's greenhouse, Coatesville (No. 86), is in the Harpers phyllite, which overlies the Chickies quartzite.

The valley is underlain by Cambrian and Ordovician limestones. West of the western boundary of Coatesville the Conestoga limestone is practically the only formation outcropping, while to the east of that line are a number of separate units. Many wells have been drilled in these limestones with different degrees of success. The 10-inch

drilled well at the Coatesville Milk Products Co. (No. 87) yields 110 gallons a minute. The water was encountered in an 18-inch opening near the bottom and rose in the well to within 17 feet of the surface. On a 60-hour test at 110 gallons a minute there was a drawdown of the water level of only 8 feet. The water has a temperature of 52° F., and is used chiefly for cooling. The 10-inch drilled well at Kirk's Ice Plants, in Coatesville (No. 88), was drilled in solid Ledger dolomite and yielded 8 gallons a minute. It is now abandoned on account of its small yield. A well at the Lukens Steel Co.'s plant (No. 89), 485 feet deep, also yielded very little water. A number of wells have been drilled in the Conestoga limestone west of Coatesville. Two drilled wells at the Keystone Mushroom Co. (Nos. 90a and 90b) yield 60 and 110 gallons a minute, respectively. These wells are only 30 feet apart, but apparently draw their water from different solution channels. (See also wells Nos. 91 to 93.) These wells show the uncertainty of drilling wells in limestone and the importance of solution channels as a source of water.

East Fallowfield Township. With the exception of very small areas of Conestoga limestone and Cockeysville marble, all of East Fallowfield Township is underlain either by the Wissahickon formation or the Peters Creek schist. The well of William Walton, at Humphreyville (No. 94), was originally a 40-foot dug well with 20 feet of rock lining. The well was drilled 40 feet deeper, making a total of 80 feet. Water was struck at 60 feet, which rose to the level of the bottom of the dug well. The well now yields 20 gallons a minute and never goes dry. The Patterson Parchment Paper Co. drilled two wells in the Wissahickon formation (Nos. 95a and 95b)—one was 1,000 feet deep and the other 140 feet deep, but both wells are abandoned on account of small yield. At Modena a number of wells were drilled ranging in depth from 40 to 60 feet, and none of them yields more than 10 gallons a minute. These wells are typical of the Wissahickon formation. The deep well shows it is usually futile to drill to great depth in search of water in the crystalline rocks. The Peters Creek schist, which overlies the Wissahickon formation, outcrops in a band of varying width which crosses the township in a generally east-west direction. (See wells Nos. 98, 99a, and 99b.)

East Marlboro and West Marlboro townships. The Baltimore gneiss is exposed in the center of an uplift which is surrounded by the younger formations except where they are cut off by faults. (See wells Nos. 100 to 105.) The Setters formation rests on the Baltimore gneiss. Several wells have been drilled in this formation at Red Lion. (See Nos. 106 to 110.) The Cockeysville marble underlies fertile valleys in both townships. In some places dug wells were successful but in other localities considerable difficulty has been encountered in obtaining successful wells. In recent years many wells have been drilled in the marble. (See Nos. 111 to 114.) The well at the Grange Hall, at Doe Run (No. 111), was drilled through weathered limestone, reported by the driller as "sand," and water was encountered at 80 feet when the bit struck solid limestone. The water rose to within 10 feet of the surface, but pumping at the rate of 5 gallons per minute draws the water level down more than 20 feet. The well at the Highland Dairy Products Co., Doe Run Station (No. 112), has the first 20 feet dug

10 feet in diameter, the lower 45 feet being drilled 6 inches in diameter. The large diameter of the dug part of the well affords ample storage because the water rises within 4 feet of the surface. The well is pumped at the rate of 75 gallons a minute for 1½ hours with a drawdown of 20 feet, and that level can be maintained if the well is pumped at the rate of 25 gallons a minute. In the well of Mrs. Bakestraw, Willowdale (No. 113), the water was encountered at the junction of the limestone and underlying schist and rose within 42 feet of the surface. The well of J. Crosson (No. 114) is also in limestone or marble. The water was encountered at 30 feet below the surface and rose 15 feet in the well. Apparently none of these wells encountered large solution channels capable of supplying large volumes of water.

The Wissahickon formation, which overlies the Cockeysville marble, is at the surface over large areas in both townships and supplies a number of wells (See Nos. 115 to 119).

Kennett and New Garden townships. The most striking feature in Kennett and New Garden townships is the limestone valley with its numerous mushroom plants. The Baltimore gneiss supplies a number of wells (See Nos. 120 to 126). The well on the property of Canby Donaldson (No. 121) is used to supply about 25 houses in Hamorton. The water is pumped by windmill or gasoline engine into a concrete reservoir 14 by 13 by 12 feet, and is distributed by gravity. East of Kennett Square, along U. S. Route 1, a number of wells have been drilled in the Baltimore gneiss. The Setters formation outcrops north of the valley in which Kennett Square is situated. (See wells Nos. 127 and 129.) Several quarries have been opened which afford excellent exposures of this formation. A large number of wells have been drilled in the Cockeysville marble, chiefly to obtain water for use in the mushroom industry. (See Nos. 128, and 130 to 138.) These wells show a considerable range of possibilities for wells in this rock. Some of them yield rather large supplies.

The Wissahickon formation is also an important source of ground water because it is widely distributed over both townships. (See wells Nos. 139 to 144.) Gabbro is the only igneous rock in the area which is important as a source of water and a number of wells have been drilled into it. (See Nos. 145 to 148.) These wells have larger yields than most wells drilled in gabbro. The well of John D. Miller (No. 147), only 28 feet deep, flows 6 gallons a minute, and yields 30 gallons a minute when the water level is pumped down 10 feet. Kennett Square is supplied with surface water from a tributary of Red Clay Creek.

London Grove, Franklin, and London Britain townships. The Baltimore gneiss outcrops in London Grove Township but not in Franklin or London Britain townships.[1] In the vicinity of Chatham the wells, especially the deeper drilled wells, encounter rather hard water in this gneiss as is shown by the analyses of waters from wells Nos. 149a and 149b. Considerable feldspar is reported in the vicinity, and this may account for the presence of calcium. Data on wells drilled in the Setters formation in this area are lacking, but it should yield small supplies of good water as it does in New Garden Township. The Cockeysville marble is exposed in the vicinity of Avondale and south of Lan-

[1] Area shown in U. S. Geol. Survey Geologic Atlas, Elkton-Wilmington, Md.-Del.-N. J.-Pa. folio (No. 211) 1920, is in part Wissahickon formation.

denberg. The town of Avondale obtains its supply from a quarry in the town. It is reported that this marble quarry was abandoned because water came in faster than the pumps could handle it. The quarry is full of water and more than supplies the needs of the town. It is reported that the water enters the quarry by open joints in the marble. The water is pumped into the distributing system which is connected to a 396,000 gallon equalizing reservoir 120 feet above the pump. (See analysis.) In the well at the public school in Avondale (No. 152), water was struck at 50 and 120 feet below the surface. The water stands 40 feet below the surface in the well, and in a 5-hour pumping test at 15 gallons a minute the drawdown was only a few feet. The well of the Pusey-Jones Abattoir & Ice Co. (No. 153) is in disintegrated marble. The water enters the well about 90 feet below the surface and rises within 11 feet of the surface. The original pumping test was for a period of 10 hours at the rate of 75 gallons a minute with only a small drawdown. The well of Charles Johnson (No. 154) is drilled into the micaceous phase of the marble known as "bastard granite." The water was encountered 80 feet below the surface and rose to 60 feet. When the well is pumped at the rate of 10 gallons a minute the drawdown is small. Other wells drilled into the Cockeysville marble are Nos. 150 and 151.

The Wissahickon formation, which overlies the Cockeysville marble, outcrops over a large area. The drilled well of the borough of West Grove (No. 155), which is used for a reserve supply, is in this formation. About 5 gallons a minute of water was struck in the first 120 feet and the main supply was encountered between 120 and 130 feet below the surface. From 130 to 380 feet very little water was encountered. The water rises within 80 feet of the surface and a deep-well pump is used to lift it to the surface. (See also Nos. 156 to 158.)

Gabbro occurs in small outcrops. Pegmatite dikes, from which considerable feldspar has been mined, occur in the area and are often encountered in drilling. The drilled well of Arthur Yettman, at Baker (No. 159), suggests that the pegmatite may be a better source of ground water than some of the other rocks in the area.

The borough of West Grove obtains most of its water from wells in the marble. A chief source of supply is a dug well 35 feet deep and 8 feet in diameter. The water rises within 5 feet of the surface, but when pumped at the rate of 85 gallons a minute the water level is drawn down 25 feet and it takes 8 hours for the well to refill. The surplus water from the Pusey-Jones Abattoir & Ice Co. well (No. 153) is also used by the borough. A reserve supply is obtained from well No. 155, which is in the Wissahickon formation. The water is pumped to a 95,000-gallon standpipe and is distributed by gravity.

Sadsbury and West Sadsbury townships. Chester Valley cuts across the southern end of both Sadsbury and West Sadsbury townships. The Baltimore gneiss forms the core of the hill north of the valley and is an important source of ground water. (See wells No. 160 to 162.) The Wissahickon formation, which forms the hills to the south of Chester Valley, is unimportant as a source of ground water in these townships on account of its limited area of outcrop. The Cambrian formations are on both sides of the core of Baltimore gneiss but only a few wells have been drilled into them. The Parkesburg Water Co.

formerly used a drilled well 175 feet deep which is reported to have obtained a large supply from the Hellam conglomerate member of the Chickies quartzite. At present it has 11 dug wells on the north side of the town in a favorable location at the foot of a hill. These dug wells are all about 30 feet deep and so arranged that the water flows to a concrete basin. The yield from these wells varies greatly and is much reduced in dry seasons. (See analysis.) The Chester Valley in these townships is underlain by the Conestoga limestone which supplies a large number of wells. (See Nos. 164 to 171.) Five wells at Stottsburg range in depth from 35 to 50 feet and yield a few gallons per minute each. At Pomeroy, 12 wells range from 77 to 220 feet in depth and from 4 to 110 gallons per minute in yield.

The borough of Parkesburg is supplied by the Parkesburg Water Co. with water which is derived in part from dug wells in the Harpers phyllite located on the north side of the borough, in part from springs in the Wissahickon formation on the southwest side, and in part from a spring-fed tributary of Octoraro Creek. The water from the springs and the dug wells flows by gravity into a collecting basin but the water from the stream is pumped to the collecting basin. The water is pumped from the collecting basin to a reservoir on a hill at the northwestern edge of the borough, from which it is distributed by gravity. The advantage of obtaining water supplies from the schists and phyllites is obvious when the analyses of water from the different types of rock are compared.

West Fallowfield, Highland, and Londonderry townships. The two formations of importance as sources of water in these townships are the Wissahickon formation and the Peters Creek schist. The Conestoga limestone and the Cockeysville marble both outcrop but their areal extent is small.

The Wissahickon formation occurs in two belts—one north and one south of the Peters Creek schist. Wells No. 172 to 175 are supplied by the Wissahickon formation. The Parkesburg Water Co. uses the water from 17 small springs located 1½ miles southwest of Parkesburg. The total yield of these springs is only about 20 gallons a minute but is subject to considerable fluctuation depending upon the weather. The mineral content of this water is less than one-seventh and the hardness less than one-tenth that of the water from the well of the Conestoga Traction Co., which is drilled in the Conestoga limestone. (See analysis.) The Peters Creek schist occupies a syncline of varying width in the Wissahickon formation. A number of wells have been drilled in this schist. (See Nos. 176 to 178.) Sixteen wells drilled in the Peters Creek schist in Cochranville in recent years range in depth from 60 to 150 feet and in yield from about 10 to 15 gallons a minute. A well at the creamery (No. 177a), 99 feet deep, yielded less than 1 gallon a minute and was abandoned. Another well (No. 177b), drilled only a few feet away, to the depth of 151 feet, yields 70 gallons a minute. The water stands 15 feet below the surface and is drawn down only a few feet when pumped.

Upper Oxford, Lower Oxford, and Penn townships. The important water-bearing formations in Upper Oxford, Lower Oxford, and Penn townships are the Wissahickon formation and the Peters Creek schist, which are similar aquifers. However, the waters from the Peters Creek

schist are frequently somewhat harder than those from the Wissahickon formation. Many wells have been drilled in the Wissahickon formation. (See Nos. 179 to 190.) At Lincoln University a number of dug wells, about 50 feet deep, are now abandoned. A drilled well, 124 feet deep (No. 189a), yields 8 gallons a minute. The water stands 35 feet below the surface and is pumped by a deep-well pump driven by a gasoline engine. This well is now held in reserve. The main supply is obtained from an 8-inch well, drilled 184 feet deep at the power house in 1907 (No. 189b). The water rises in this well within 20 feet of the surface and is lifted by compressed air at the rate of 38 gallons a minute. The water is pumped to two tanks in Lincoln Hall, each holding 4,000 gallons and then distributed by gravity to the buildings. The average daily consumption is 20,000 gallons. The borough of Oxford has drilled four wells (Nos. 190a to 190d)—two at the reservoir just north of the town, and two a quarter of a mile north on the Stallard farm. The first well (No. 190a) is 1,004 feet deep and yields 45 gallons a minute. Apparently very little water enters the well below the depth of 350 feet. Less than 100 feet distant is another drilled well (No. 190b), 540 feet deep, which yields 35 gallons a minute. However, when both wells are pumped simultaneously the yield of the shallower well is reported to be reduced about one-half. The well near the farm house on the Stallard Farm (No. 190c) is 478 feet deep and yields 40 gallons a minute. At times this well overflows. When pumped at the rate of 85 gallons a minute for two hours, the drawdown was 144 feet and 12 hours elapsed before the well again overflowed. The well of J. G. Leek at Bethel Church (No. 191) is in Peters Creek schist.

West Nottingham, East Nottingham, New London, and Elk townships. The most widespread formation in these townships is the Wissahickon formation, which furnishes small supplies of water to many wells. (See Nos. 192 to 205.) The Peters Creek schist outcrops in West and East Nottingham townships. Its water-bearing properties resemble those of the underlying Wissahickon formation except that the water averages somewhat harder. Serpentine occurs extensively, particularly in East and West Nottingham townships, in which are situated the famous "barrens" from which chromite has been obtained. Areas underlain by serpentine are well known for their thin barren soil, their bald, or sparsely scrub-covered hills, and their infertile valleys. The serpentine areas are thinly inhabited and the main dependence for water supply in these areas is on springs and shallow dug wells. In recent years, however, a number of wells have been drilled, particularly along the Baltimore-Philadelphia Highway. (See wells Nos. 206 to 212.) The water is hard, due chiefly to the abundance of magnesium. (See analyses). Small springs are rather common in the serpentine areas. A small spring occurs just below the Baltimore-Philadelphia Highway about 1 mile north of Sylmar. Its yield varies with the season, and in summer is only a gallon or two a minute. The temperature of the water at the time the spring was visited was 53° F. Pegmatite dikes cut the serpentine, and large trenches usually partly filled with water mark where the feldspar has been mined. The water levels in these trenches apparently represent the water table, but no attempt has been made to obtain water supplies from the dikes and their water possibilities are not known.

WELLS DRILLED IN CHESTER COUNTY

No.	Owner	Location	Depth	Diamete	Water-bearing formation	Depth to water level	Yield	Remar s
			Feet	Inches		Feet	Gals. min.	
1	Lewis Hughes	S. of Chester Valley P. O.	210	6	Wissahickon formation		8	
2	Mr. Liv'gston	1 mile N. of Strafford	290	6	do		10	
3a	Samuel Given	Howellville	50	5⅝	Conestoga limestone			16 holes at quarry; all practically dry.
3b	do	do	152	5⅝	do			4 holes at quarry; little or no water.
4a	Norman J. Green	Berwyn	212	6	Wissahickon formation		2	
4b	do	do	110	6	do		8	
5	Dr. Nielson	1 mile S. of Berwyn	125	6	do		16	
5a	Handley Stokes	3 miles S. of Daylesford	211	6	Baltimore gneiss	20	5	All water in first 50 feet.
5b	Mrs. Davis	do	115	6	do	40	3	Drawdown to bottom.
5e	Dr. Alfred Stengel	1¼ miles E. of Whitehorse	100	8	Gabbro		125	Flowed a few g.p.m.; drawdown 12 feet at 125 g.p.m.
6	Samuel Given	Duffryn Mawr	90	5⅝	Wissahickon formation	18	10	
7a	I. F. Gill	do	40	6	do		60	
7b			102	6	do		10	
8	William Townsley	Malvern	65	6	do		16	
9	Charles E. Highly	do	75	6	do		25	
10	Rev. Patrick Dwyer	Frazer	157	6	do		4	
11	Pennsylvania Railroad	do	100	6	do	14	15	
12	E. H. Jacob	West Chester	100	6	Baltimore gneiss		100	
13	Fitzpatrick & Son	do	98	8	do		[illegible]	
14	Harry Brogan	do	68	6	do	16	18	
15	West Chester Dairy Co.	do	150	6	do		25	Small drawdown.
16	Sharpless Creamery	do	125	6	do		15	
17	James Chubbs	1 mile N. of West Chester	135	6	Wissahickon formation	68	20	See analysis.
18a	Ed. H. Jacob	Greenhill	500	6			100	Brown rock.
18b	do	do	300	6			65	do
18c	do	do	180	6			75	do
18d	do	do	150	6			50	do
18e	do	West Chester	100	6	Gabbro		120	Temperature, 50° Well No. 1.
18f	do	do	100	6	do		100	Well No. 2.
18g	do	do	100	6	do		100	Well No. 3.
18h	do	do	140	6	do		17	Well No. 4
18i	do	do	152	6	do		100	Well No. 5.
18j	do	do	165	6	do		17	Well No. 6; see analysis.
18k	do	do	89	6	do		12	Well No. 7

19	S. C. Bolling	do	300	6	Gabbro (?)	30	8	
20	Mr. Walters	do	56	6	do		20	Hard black rock.
21	Charles Townsend	do	87	6	do		6	do
22	Mr. McGowan	do	78	6	do		10	
22a		do	60	6	do		20	
25	Mr. Bryan	1½ miles S. of West Chester	58	5⅝	Baltimore gneiss		45	Small drawdown, numerous crevices.
26	J. Bauer	¾ mile SW. of Westtown	140	6	do		7	Hard black rock.
27	Red Man's Hall	Tanguy	45	5⅝	do		10	
28	School House	do	30	5⅝	do		15	
29	Westtown Boarding School	Westtown	40-200	5⅝	Wissahickon formation			7 wells; combined yield 200 g.p.m.
30	Charles Palmer	1½ miles NE. of Westtown	62	6	do		30	Soapy rock.
31	Charles Mathers	1 mile E. of Lenape	180	6	do		20	
32	Franklin Sharpless	Westtown	156	6	Baltimore gneiss		3	Well was unfinished when visited.
33	Mr. Huntsberger	Snowdensville	150	6	Brunswick formation		25	
34	Mr. Keene	do	125	6	do		15	
35	Jerome Keeley	Slonaker	125	6	do		20	
36	R. Heasten	¼ mile NE. of Slonaker	100	6	do		20	
37	Walter Bell	Cedarville	125	6	Brunswick formation		8	
38	James Swoyer	do	125	6	do		8	Wells in vicinity similar.
39	J. Marshall	1 mile NW. of Cedarville	60±	6	do		10	
40	Kline Realty Co.	¾ mile S. of Pottstown	150	6	do		50	
41	Ruben Updegrove	¾ mile W. of Cedarville	150	6	do		12	
42	Bucktown Garage	Bucktown	65	6	Stockton formation		6	
43	Mr. Groff	do	50	6	do		5	
44	South Coventry School	do	85	6	do		15	
45	Penrose Brothers	Coventryville	100	6	do		20	
46	Parker Noble	¾ mile NW. of Harmonyville	125	6	Brunswick formation		20	
47		Loag	54	6	Baltimore gneiss		12	
48	Henry Kurtz	½ mile SE. of Elverson	70	6	Quartz monzonite		15	
49	Dolfinger Creamery	Elverson	80	6	Chickies quartzite		40	White sandstone. See analysis.
50	Henry Zook	do	84	6	do		20	Wells in vicinity similar.
51	J. Harvey Emery	Chester Springs	129	6	Baltimore gneiss	35	3½	Drawdown 50 feet.
52	Brandywine Fruit Farm	½ mile E. of Reeceville	50	6	do		3	Small yield.
53	Sexton's house	Brandywine Manor	80	6	Chickies quartzite		2	
54	Harbison Dairy	Byers	300	6	Baltimore gneiss		8	
55	Imperial Graphite Co.	do			do			Two wells similar to No. 54.
56	J. Hoopes	1 mile N. of Caln	78	6	do		10	Large drawdown.
57	John Y. Woodward	¼ mile E. of Coatesville	135	6	Wissahickon formation		3	Several other wells in vicinity.
58	William Rudolph	Fisherville	55	6	Baltimore gneiss		6	
59		Thorndale	40-60	6	Wissahickon formation		5+	Several additional wells; soft water.

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
60	W. J. Harvey	do	70	6	Conestoga limestone		4	
1	M. Rambeau & Sons	do	100	6	do			Small yield.
62	Howard Darlington	do	100	6	do			Small yield; "quicksand" reported.
63	Charles E. Mathers	½ mile NE. of Wawaset	124	6	Baltimore gneiss		12	
64	George Leslie	Copesville	78	6	Wissahickon formation		12	Large drawdown.
65	J. B. Thompson Co.	2 miles SW. of Downingtown	90	6	do		5	
66	Paul Pearson	Harmony Hill	75	6	Peters Creek schist		5	
67	Chadds Ford Cons. School	Near Chaddsford	78	6	Baltimore gneiss		28	5-foot drawdown in a 5-hour pumping test.
68	I. R. Comfort	¼ mile SW. of Lenape	130	6	Wissahickon formation		18	Large drawdown.
69	Mr. Parker	Parkersville	120	6	do		20	
70	Arthur Fry	do	110	5⅝	Baltimore gneiss		15	
71	N. Lancaster	Chaddsford Junction	110	5⅝	Wissahickon formation		15	Small drawdown.
72	R. Hollingsworth	Fairville	40	5⅝	do		4	Close to gabbro contact.
73	Mr. Grube	1½ miles NE. of Honeybrook	42	6	Baltimore gneiss		10	
74	Charles Chambers	Suplee	55	6	Quartz monzonite		5	
75	Dolfinger Creamery	Birdell	38	6	do		30	
76	Samuel Crouse	Cupola	60	6	Anorthosite		5	
77	George Dunlap	¾ mile W. of Wagontown	70	6	Baltimore gneiss		20	Small drawdown. Brown shale.
78	Horace Dunlap	do	60	6	do		3	
79	I. F. McFarlan	Wagontown	50	6	do		10	Large drawdown.
80	Martin Miller	2 miles NE. of Compass	70	6	Chickies quartzite		5	
81		1¼ miles NW. of Coatesville	50	6	Baltimore gneiss		2	Large drawdown.
82		Steelville	40–120	6	Wissahickon formation			Several wells; small yield.
83		On ridge south of valley	100–200	6	do			Several small wells.
84	William Heffner	West of Coatesville	40	6	Chickies quartzite		10	Good wells in vicinity.
85		On ridge N. of Valley		6	do			Water level 50 to 200 feet below surface; small producers.
86	Brown's Greenhouse	Coatesville	160	6	Harpers phyllite		5	
87	Coatesville Milk Products Co.	do	225	10	Ledger dolomite	17	110	8-foot drawdown. See analysis.
88	Kirk Ice Plant	do	360	10	do		3	Solid; large drawdown; abandoned.
89	Lukens Steel Co.	do	485	6	do			Small yield.

90a	Keystone Mushroom Co.	Pomeroy	186	8	Conestoga limestone		60	Large drawdown.
90b	Keystone Mushroom Co.	Pomeroy	220	8	Conestoga limestone		110	Large drawdown.
91a	Richard Copeland	1½ miles E. of Pomeroy	60	6	do		10	Large drawdown; water enters at 26 feet.
91b	do	do	60	6	do		10	500 feet from 91a.
92a	William Casey	do	100	6	do		3	Large drawdown; only 30 feet from 91a.
92b		1 mile W. of Coatesville	100	6	do		30	Small drawdown.
93	A. Westman	do	70	6	do	5	10	Water enters at 14 feet. See analysis.
94	William Walton	Humphreyville	80	6	Wissahickon formation		20	
95a	Patterson Parchment Paper Co.		1,000	6	do			Abandoned because of small yield.
95b	do		140	6	do			do
96	Modena		40–60		do			Household wells.
97	Boxtown School	Coatesville	200	6	do		3	Abandoned.
98	Warren Webster	Ercildoun	140	6	Peters Creek schist	60	20	See analysis.
99a	William Miles	Youngsburg	100	6	do		5	
99b	do	¾ mile E. of McWilliamstown	160	6	do		5	
100	George Derlvier	Longwood	36	5⅝	Baltimore gneiss		15	
101	P. S. Dupont	do	100	5⅝	do		15	
102	Edward Walton	London Grove	50	6	do		20	
103	James Logan	½ mile E. of London Grove	50	6	do		20	
104	Eugene Levis	½ mile E. of Clonmell	56	6	do		8	Large drawdown.
105	Plunkett Stewart	½ mile N. of Upland	85	6	do		20	Small drawdown.
106	Curtis Vandiver	Red Lion	80	5⅝	Setters formation		2	
107	Morris Baldwin	do	76	5⅝	do		15	Mica rock.
108	Wayne Cox	do	56	5⅝	do		15	
109	Atlantic Telephone & Telegraph Co.	do	110	5⅝	do		15	
110	Frank Leo	¾ mile E. of Greenlawn	95	6	do		10	Large drawdown.
111	Grange Hall	Doe Run	80	6	Cockeysville marble		5	Large drawdown.
112	Highland Dairy Co.	Doe Run Station	65	6	do (?)	4	25	Upper 20 feet dug; 10 feet in diameter. See analysis.
113	Mrs. Rakestraw	Willowdale	135	6	do		10	Large drawdown.
114	J. Crosson	do	68	6	do		4	
115	Sharpless Creamery	Buck Run	75	6	Wissahickon formation		12	
115a	William Jones	Doe Run Station	60	6	do	22	15	Large drawdown.
116	Dupont Farm	¾ mile N. of Doe Run	220	6	do	45	8	do
117	Harvey Worton	Upland	80	6	do	30	15	Small drawdown.
118	Consolidated School	Unionville	165	6	do	60	25	
119	Mrs. Walker	do	135	6	do	80	10	Yields 10 g.p.m. when water level is lowered to bottom of well.
120	George Rouse	Longwood	36	5⅝	Baltimore gneiss		15	
121	Canby Donaldson	Hamorton	86	5⅝	do		10	Hamorton supply.
122	Dr. James Walker	do	60	5⅝	do	20	15	See analysis.

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
123	Mrs. Nelson	do	50	$5\frac{5}{8}$	do			Yielded less than 1 gallon an hour; abandoned.
124	Norris Schaffner	Mendenhall	141	6	do		$2\frac{1}{2}$	
125	do	do	34	6	do		7	
126	Ed. Fahey	East of Kennett Square	84	6	do	56	12	See analysis.
127	Wayside Camp	½ mile E. of Toughkenamon	30	6	Setters formation	8	20	
128	Pennsylvania Railroad Station	Toughkenamon	85	6	Cockeysville marble		20	
129	Richards Brothers	do	100	6	Setters formation		25	20 gallons a minute before shooting.
130	Horace Catini	do	260	8	Cockeysville marble		40	
131	Bancroft Swain	Kennett Square	69	6	do		110	
132	do	do	80	6	do		100	
133	do	do	280	6	do		11	
134	do	do	80	6	do		20	
135	Kennett Ice Co.	do	69	6	do		60	Flows 2 g.p.m. See analysis.
136	Yateman Greenhouse	do	50	6	do		50	Small drawdown; water rises nearly to surface.
137	Edward Darlington	Avondale	70	6	do		20	
138	do	do	34	$5\frac{5}{8}$	do		5	
139	Newland Brothers	1 mile SE. of Avondale	84	6	Wissahickon formation		15	Dark brown sand.
140	Frank Leo	½ mile S. of Toughkenamon	65	6	do	30	8	
141	Thompson Brothers	1½ miles SW. of Kennett Square	154	6	do	10	20	
142	L. Thompson	2 miles SW. of Kennett Square	140	6	do (?)	20	30	
143	K. Crosson	Landenberg	65	6	do	12	12	Drawdown 18 feet.
144	Quill Brothers	½ mile NW. of Kaolin	154	6	do	40	20	Dug to 54 feet.
145	Samuel Wickersham	1 mile SE. of Avondale	40	6	Gabbro	8	15	Black rock.
146	Prinnell Brothers	1 mile SE. of Avondale	135	6	do		5	Large drawdown.
147	J. D. Miller	do	28	6	do		30	Hard black rock; flows 6 g.p.m.; see analysis.
148	John Leo	½ mile S. of Toughkenamon	85	6	do	20	8	
149a	C. H. Graham	Chatham	28		Pegmatite	25		Dug well 4 feet in diameter; see analysis
149b	do	do	125	6	do		10	20 feet from No. 149a; see analysis.
150	Esther West	Avondale	175		Cockeysville marble			Yields less than 1 g.p.m.
151	Thomas Baker	do	50		do		10	

152	Public School	do	128	6	do		15	5-hour test, small drawdown
153	Pusey-Jones Abattoir Co.	West Grove	98	6	do	11	75	Disintegrated rock. See analysis.
154	Charles Johnson	¾ mile N. of Baker	120	6	do		10	Considerable mica in the rock.
155	Borough of West Grove	West Grove	380	8	Wissahickon formation		20	Most water encountered in first 130 feet.
156	William Wood	½ mile SW. of Avondale	70	6	do		2	Large drawdown; water enters at 58 feet.
157	Charles Patton	1 mile SW. of Avondale	125	6	do		5	Large drawdown; water enters at 60 and 120 feet.
158	John Dougherty	Wickerton	120	6	do		8	Considerable mica in the rock; small drawdown.
159	Arthur Yettman	Baker	55	6	Pegmatite	20	30	Water enters at 30 feet.
160	Daniel Kaufman	2 miles E. of Christiana	121	6	Baltimore gneiss		3	
161	Daniel Smoker	1¼ miles N. of Parkesburg	45	6	do		15	
162	Joseph Cephus	½ mile N. of Parkesburg	80	6	do	60	6	On high hill.
163	Parkesburg Water Co.	Parkesburg	30		Harpers phyllite			Eleven dug wells; see analysis.
164	Conestoga Traction Co.	Near Parkesburg	30	6	Conestoga limestone	10	5+	See analysis.
165	Samuel Wightman	Parkesburg	100	6	do		5	
166	William Poultney	do	220	6	do		30	Small drawdown.
167	Henry Hatt	do	80	6	do		30	do
168	Ralph Gray	do	77	6	do		30	do
169	Lewis Jarvis	do	86	6	do		30	do
170	Edward Matsh	do	78	6	do		30	do
171	Pomeroy Manor	Pomeroy Manor	90-120	6	do		2±	2 wells.
172	James Thompson	¼ mile SE. of Parkesburg	100	6	Wissahickon formation		3	
173	William Park	Daleville	100	6	do	30	8	Small drawdown.
174	James Y. Smith	2½ miles NW. of Chatham	60	6	do	18	12	Water enters at 40 feet.
175	White Horse Hotel	2 miles NW. of Chatham	100	6	do		18	Small drawdown.
176	A. Boggs	Cochranville	90	6	Peters Creek schist	10	8	Hard black rock.
177a	Creamery	do	99	6	do		1	Abandoned.
177b	do	do	151	6	do	15	70	Only a few feet from No. 177a; see analysis.
178	Methodist Parsonage	do	80	6	do		8	Small drawdown.
179	Elizabeth Galvin	½ mile E. of Bethel church	70	6	Wissahickon formation		5	
180	Hugh Monaghan	1¼ miles NE. of Tweedale	173	6	do		8	
181	J. Hall	Faggs Manor	130	6		30	20	Water enters at 95 feet.
182	J. H. Earhart	1½ miles W. of Hayesville	80	6	Wissahickon formation		10	
183	Samuel Ross	1½ miles SW. of Hayesville	54	6	do		8	
184	Frank Wilson	1 mile NE. of Oxford	133	6	do		15	
185	T. E. Connor	1¾ miles NE. of Oxford	59	6	do		10	
186	Andrew McIntyre	2 miles NE. of Oxford	139	6	do		8	Weathered rock requiring casing to 88 feet.
187	J. Wentz	1½ miles E. of Oxford	84	6	do		10	Cased to 44 feet.

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
188	Philip Cope	Lincoln University	77	6	Wissahickon formation		10	Cased to 60 feet.
189a	Lincoln University	do	124	6	do		8	
189b	do	do	184	8	do	20	38	See analysis.
190a	Borough of Oxford	Oxford	1,004	8	do		45	See analysis.
190b	do	do	500	8	do		35	About 100 feet from No. 190a.
190c	do	do	478	8	do	Flows	40	Holland farm; see analysis.
190d	do	do	300	8	do		25	
191	J. G. Leek	Bethel Church	90	6	Peters Creek schist		5	
192	George McCleary	New London	65	6	Wissahickon formation	25	15	"Shelly black rock"; water enters at 35 feet.
193	Mr. Lisle	do	75	6	do	15	20	Water enters at 60 feet.
194	Morris Crosson	1 mile SE. of New London	94	6	do	22	12	"Sand"; water enters at 35 and 65 feet.
195	George Stevens	Barnsley	92	6	do		10	
196	Oxford Ice Plant	Oxford	139	6	do		25	
197	Round House, Pa. Railroad	do	100	6	do			Locomotive use; large supply.
198	Smith Ice Cream Plant	do	130	6	do		10	
199	Harry Lloyd	$1\frac{1}{2}$ miles E. of Nottingham	101	6	do		10	
200	Florence Pugh	$\frac{3}{4}$ mile SW. of Hickory Hill	93	6	do		8	4 similar wells in vicinity.
201	Scott Silver	Nottingham	160	6	do	14	30	Drawdown when pumping 10 g.p.m. is less than 10 feet; see analysis.
202		Elk Mills	50±	6	do		3	
203	Milton Todd	$\frac{1}{3}$ mile E. of Nottingham	106	6	do		10	
204	Glenroy Creamery	Glenroy	180	6	do		5	Abandoned.
205	C. A. Giffing	do	75±	6	do		1	
206	A. Hines	$\frac{1}{2}$ mile E. of Nottingham	77	6	Serpentine		5	
207	Anthony Hanson	1 mile SE. of Nottingham	100	6	do		5	
208	Sutton & Corson	1 mile N. of Sylmar	129	6	do		25	See analysis.
209	Kennedy Refractory Co.	do	72	6	do		10	
210	Atwood Montgomery	$\frac{1}{2}$ mile N. of Sylmar	47	6	do		5	Dug well deepened.
211	Frank Campbell	$\frac{3}{4}$ mile SW. of Nottingham	100	6	do		5	See analysis.
212	E. M. Kirk	$2\frac{1}{4}$ miles SW. of Nottingham	121	6	do		10	

CUMBERLAND COUNTY

GENERAL CONDITIONS

Cumberland County is separated from Perry County on the north by the crest of North or Blue Mountain and from Dauphin County on the east by Susquehanna River. On the south it is bordered by Franklin, Adams, and York counties. The county has an area of 528 square miles and a population, according to the United States Census of 1930, of 68,236, giving an average of 129.2 inhabitants per square mile. The county is essentially a rural area, and the rural population comprises about two-thirds of the whole. The same census reports that there are 2,932 farms in the county. The principal towns are Carlisle, the county seat, Mechanicsburg, Shippensburg, and the towns on the west bank of the Susquehanna, which are suburbs of Harrisburg. The needs of many of the inhabitants for water have long been supplied by springs and dug wells. Many of the dug wells are very old and little data concerning them are available. Drilled wells are becoming popular and data on a number were obtained. Springs are numerous and some of them, such as Mount Holly and Boiling Springs, (see Plate 3, B) are well known.

The results of the detailed study of the geology of this county have not been published but the formations present extend from areas upon which reports have been published. The following geologic column has been taken from sources indicated in the footnote.

Geologic column for Cumberland County[1]

Age	Name and description	Thickness	Water-bearing properties
Upper Ordovician	Juniata formation. Soft red sandstone and shale with some hard sandstone and conglomerate.	Feet 68–350	Unimportant as a source of ground water.
Upper and Middle Ordovician	Martinsburg shale. Soft, gray, green, yellow, and black shales with thin sandy and calcareous shales and thin limestone.	1800?	Wells usually yield small supplies of hard water at moderate depths.
Middle Ordovician	Leesport "cement rock".	200±	Rather poor water horizon.
	Chambersburg limestone. Thin bedded, dark limestone with irregular clay partings.	250±	A somewhat poorer water horizon than the underlying limestones and dolomites.
Lower Ordovician	Stones River limestone. Very pure, thin-bedded, even grained, dove-colored limestone with magnesian layers.	1000±	Frequently cavernous and consequently a good water-bearing horizon. Wells in solid limestone may be failures.
	Beekmantown limestone. Thick-bedded, rather pure limestone, usually finely laminated.	2000±	Some large springs and excellent wells. Yield of wells dependent upon well intersecting water-bearing solution channels.
Upper Cambrian	Conococheague limestone. Thin-bedded, blue limestone, finely banded by thin hard laminae.	1000±	Not a good ground-water horizon. Some wells yield large supplies, most of them yield less than 20 gpm.

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Upper and Middle Cambrian	Elbrook limestone. Gray to pale blue, shaley limestone and calcareous, papery shale with some thick, impure limestones.	1500±	A poor ground water horizon. Most wells yield small supplies.
Middle (?) and Lower Cambrian	Waynesboro formation. Slabby, gray, calcareous sandstones or sandy limestones and hard, slaty, purple shale.	1000±	Poor water horizon. Most wells yield small supplies.
Lower Cambrian	Tomstown dolomite. Massive and thin-bedded dolomite, in part cherty and magnesian with considerable shale and soft white clay at base.	1000±	Wells in this dolomite yield small supplies except those which intersect large water-bearing solution channels.
	Antietam quartzite. Coarse grained, white and gray quartzite and sandstone.	800±	Fairly good water-bearing formation.
	Harpers phyllite. Dark banded schist at top and bottom with great thickness of massive white quartzite (Montalto member: thickness 2000± feet) in middle.	3000±	Schist is a poor water-bearing material but the quartzite is a more favorable one. Formation outcrops in rugged areas where small springs furnish adequate supplies.
	Weverton sandstone. Coarse, gray, feldspathic sandstone and white quartzose sandstone with purplish arkose and hard, purple quartz conglomerate at base.	750	Fairly good water-bearing formation. Wells should yield medium supplies of soft water.
	Loudoun formation. Gray and purplish arkosic conglomerate and fine sericite slate.	550	A rather poor water-bearing formation which outcrops on thinly inhabited, rugged mountain slopes.
	——Unconformity——		
Algonkian	Metabasalt, altered basalt lava. Massive to schistose greenstone.	?	A rather poor water-bearing horizon.
	Aporhyolite. Altered rhyolite lava; sericite schist at top.		do

[1] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg–Chambersburg folio (No. 170), 1909, and Stose, G. W., and Bascom, F., U. S. Geol. Survey, Geol. Atlas, Fairfield-Gettysburg folio (No. 225), 1929, Stose, G. W., Unconformity at the base of the Silurian in southeastern Pennsylvania: Bull. Geol. Soc. Am., vol. 41, pp. 639-640, 1930; Stose, G. W., New Cumberland Quadrangle, Penn. Top. and Geol. Survey (unpublished).

The formations in the geologic column are described in the introductory part of this report.

TOWNSHIP DESCRIPTIONS

East Pennsboro, Hampden, Upper and Lower Allen townships. The oldest rock at the surface in these townships is a small belt of Conococheague limestone lying in Upper and Lower Allen townships. The limestones which crop out along Yellow Breeches Creek are the Beekmantown limestone and the Leesport "cement rock." Wells in the Beekmantown limestone in Grantham average about 100 feet in depth, and most of them yield less than 10 gallons a minute. (See Nos. 1 and 2; see also Nos. 3 to 6 for wells in Bowmansdale and New Cumberland.) The well at the New Cumberland Dye Works (No. 4) is 400 feet deep and yields 50 gallons a minute. This well was drilled through 200 feet of shale before the limestone was reached, but the water encountered in the limestone rises to within 40 feet of the surface. The well at Kepner's Greenhouse, in New Cumberland (No. 5), is 250 feet deep and yields 30 gallons a minute.

The Beekmantown limestone is overlain by the Leesport "cement rock" and the Martinsburg shale which form the low hills in Upper and Lower Allen townships. Several wells in the village of Shepherdstown range in depth from 100 to 120 feet, and yield about 10 gallons a minute (See Nos. 7 to 10).

The Conococheague limestone is overlain by the Beekmantown, Stones River, and Chambersburg limestones, which occur in a depression of varying width between the shale hills on the north and south. Several wells drilled at the Walter Wood dairy in Lemoyne (Nos. 11a to 11c) range from 200 to 700 feet in depth, but none are reported to yield more than 2 gallons a minute. In this town a number of drilled wells have been used as cesspools. A number of wells have been drilled into the Beekmantown limestone along the Trindle Spring road, between Camp Hill and Mechanicsburg. They range from 50 to 400 feet in depth, and yield from 10 to 30 gallons a minute. The wells in the limestone along the road from Shiremanstown to Shepherdstown are similar. About six wells have been drilled at Eberlys Mill, which average about 100 feet in depth and yield from 10 to 20 gallons a minute. In this area no wells with large yields were reported and some failures have occurred. However, some excellent springs in the area yield up to 100 gallons a minute.

The Martinsburg shale underlies the hills north of the limestone valley. The well of the Summerdale Water Co. (No. 14) is 300 feet deep and yields 50 gallons a minute. This well is on the flanks of the mountain, and the water rises practically to the surface. About twenty other wells have been drilled in the vicinity, ranging from about 60 to 100 feet in depth and yielding from 5 to 10 gallons a minute. A large number of wells have been drilled in Enola averaging about 80 feet in depth and yielding from about 1 to 10 gallons a minute. Several wells in the town of Wormleysburg range from about 60 to 80 feet deep and are reported to yield from 2 to 10 gallons a minute. The strongest well in the Martinsburg shale reported in this area is the 200-foot well at the West Shore Dairy Co., at Lemoyne (No. 17), which yields 80 gallons a minute. About 40 wells have been drilled in Camp Hill. They average 80 feet in depth and are commonly reported to yield from 10 to 15 gallons a minute. There are about six drilled wells along Conodoguinet Creek, 1½ miles northwest of Shiremanstown, which average 60 feet in depth and yield about 10 gallons a minute each. The Martinsburg shale is evidently an excellent source of small supplies, and also yields fairly large supplies to a few wells.

Middlesex, Silver Spring, and Monroe townships. The Tomstown dolomite overlies the Antietam sandstone in a valley parallel to the South Mountain and is the oldest rock which crops out in Middlesex, Silver Spring and Monroe townships. About 10 wells have been drilled into this limestone in Williams Grove. They average about 80 feet in depth and are reported to yield from 10 to 50 gallons a minute. Boiling Spring, the largest spring in Pennsylvania, is just west of Monroe Township. Low ridges formed by the Waynesboro and Elbrook formations are prominent in Monroe Township. The Elbrook formation is overlain by the Conococheague, Beekmantown, Stones River, and Chambersburg limestones. The wells at Churchtown in the Conococheague limestone range from about 50 to 300 feet in depth and are

reported to yield from 5 to 50 gallons a minute. Several wells in the vicinity of Mechanicsburg, New Kingstown, and Middlesex are supplied by the Beekmantown limestone (See Nos. 21 to 23). The Trindle Spring, 1½ miles southwest of Mechanicsburg, yields more than 50 gallons a minute. The drilled wells in Middlesex average about 150 feet in depth and yield about 10 gallons a minute. The wells in New Kingstown are probably in the Stones River limestone. They range from about 50 to 100 feet deep and yield about 10 gallons a minute. A number of wells have been drilled along the Chambersburg and Harrisburg pike between Hogestown and New Kingstown. They average about 100 feet in depth and yield about 10 gallons a minute. Some of these wells are in the Stones River limestone, others in the Chambersburg limestone. A well on the H. B. McCormick Estate (No. 26) is 577 feet deep and yields 30 gallons a minute. The Juniata formation crops out on the mountain, but is unimportant as a source of ground water.

North and South Middleton and Dickinson townships. Pre-Cambrian volcanic rocks exposed in South Mountain give rise to numerous springs and yield domestic supplies to some dug wells. The Weverton sandstone crowns the tops of some of the highest elevations and crops out along the northern edge of the mountain. The Mount Holly Paper Mills has a 300-foot well (No. 27) in this rock that yields a large supply. Most wells in this formation will not yield large supplies, but the water is usually soft and very low in dissolved mineral matter. Mount Holly Spring yields about 10 gallons a minute of very soft water. (See analysis No. 36.) The Weverton sandstone is overlain by the Harpers phyllite and the Antietam sandstone. The Harpers phyllite is unimportant as a source of water. The Antietam quartzite is probably the source of much of the water encountered in the Mount Holly clay mines.

The Antietam quartzite is overlain by the Tomstown dolomite which forms a narrow valley parallel to the mountains and furnishes rather large supplies to a number of wells. (See Nos. 28 and 29.) A number of drilled wells at Boiling Springs average about 50 feet in depth and are reported to yield large supplies. The Boiling Springs yield 30 to 45 cubic feet a second, or 13,500 to 20,250 gallons a minute, and form the largest spring in Pennsylvania. These springs are shown on Plate 3, B.

The Tomstown dolomite is overlain by the more resistant Waynesboro and Elbrook formations and by younger Cambrian and Ordovician limestones. Little difficulty should be experienced in obtaining water from these limestones. A number of drilled wells in the vicinity of Carlisle are used for cesspools, indicating that the wells are in cavernous limestone. A well at Carlisle Barracks (No. 31) only 60 feet deep is reported to be in cavernous limestone and to yield 50 gallons a minute.

The limestones are overlain by the Martinsburg shale which should yield small supplies. Most of the inhabitants of North Middleton Township who live in the shale area have dug wells. Some of these wells yield hard water, and the supply is supplemented by rain water stored in cisterns. The Juniata formation outcrops high up on Blue Mountain but is unimportant as a source of water.

Frankford, West Pennsboro, Penn, and Cooke townships. The geology and ground-water conditions in these townships are similar to those in the preceding two groups of townships. The formations include the pre-Cambrian volcanic rocks, the Loudoun formation, Weverton sandstone, Harpers phyllite, Antietam quartzite, Tomstown dolomite, Waynesboro formation, the Elbrook, Conococheague, Beekmantown, Stones River, and Chambersburg limestones, the Martinsburg shale, and Juniata formation. A number of springs issue from the Tomstown dolomite, including the spring at Huntsdale. Drilled wells are not numerous in this formation. Most of the people living on the Waynesboro formation and the Elbrook limestone obtain their water supplies either from dug wells or from rain water stored in cisterns. In years past springs, dug wells, and cisterns were also the main sources of water supply in areas underlain by the younger limestones but drilled wells are increasing in popularity. The largest spring in this group of townships is probably Big Spring, 3 miles south of Newville, owned by Lindsay and Felin. It issues from enlarged joint planes in the Beekmantown limestone and is the source of Big Spring Creek. The yield of this spring is approximately 1 second-foot, or 450 gallons a minute, and the water is used to operate a mill. (See analysis.) The borough of Newville obtains its supply from Cool Spring, on the east bank of Big Spring Creek. This large spring issues from the Stones River limestone and yields about 200 gallons a minute. (See analysis.) The water is pumped to a reservoir and is thence distributed by gravity. The limestones yield large volumes of water at these springs, and wells intersecting water-bearing solution channels also yield large supplies while those drilled in solid rock may be practically dry. The limestones are overlain by the Martinsburg shale, which generally yields small supplies to wells of moderate depth.

Lower Mifflin, Upper Mifflin, Hopewell, Newton, and South Hampton townships. The oldest rocks outcropping in these townships include the pre-Cambrian volcanic rocks, the Loudoun formation, Weverton sandstone, Harpers phyllite, Antietam sandstone, Tomstown dolomite. and several overlying Cambrian and Ordovician formations (chiefly of limestone), the Martinsburg shale, and some younger rocks that outcrop high up on Blue Mountain. The water-bearing properties of these rocks have been discussed under other townships in this county. Records of 4 wells (Nos. 32 to 35) in this area are given in the table. Cisterns for storing rain water are common, both in the villages and in the country. They are used to supplement small supplies of ground water which is always hard or to furnish the entire water supply.

The Cloverdale Spring Company of Baltimore, Md. drilled three wells in limestone at Newville about 1918 for wash water at the bottling plant. The water from a well less than 100 feet deep developed an odor and its use was discontinued. A second well got a good supply at about 130 feet but after several months use the well became choked with sand. A third well found water at three horizons in less than 200 feet but the water was still muddy after being pumped 24 hours. These streams were cased off and the well sunk through limestone and clay to 354 feet without finding more water.

DRILLED WELLS IN CUMBERLAND COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1	Messiah Home	Granthan	100	6	Beekmantown limestone		5	Wells in town average 100 feet.
2	Noodle Factory	do	80	6	do	30	10	
3	Reading Station	Bowmansdale	103	6	do		3	Mud seam, 60 to 68 feet.
4	New Cumberland Dye Works	New Cumberland	400	8	do	40	50	
5	Kepner's Greenhouses	do	250	6	do		30	90 feet casing.
6		do	80	6	do		3	Sufficient for house.
7	Community Well	Shepherdstown	120	6	Martinsburg shale	50	10	Dug 60 feet.
8	Mr. Burkhardt	do	120	6	do		10	
9	Shepherdstown Hotel	do	120	6	do		10	Dug 60 feet.
10		do	100–120	6	do		10	10 or 12 wells for dwellings.
11a	Walter Wood Dairy	Lemoyne	200	6	Beekmantown limestone		2	Abandoned.
11b	do	do	300	6	do		2	
11c	do	do	700	6	do		2	
12	Coates Farm	1½ miles W. of Shiremanstown	237	6	do		20	
13	Cameron Estate	2 miles N. of Mechanicsburg	130	6	Stones River limestone	50	15	Well on hill.
14	Summerdale Water Co.	Near Overview	300	8	Martinsburg shale		50	Water rises to top of well.
16	Mrs. Hipple	Wormleysburg	200	6	do	20	10	
17	West Shore Dairy Co.	Lemoyne	200	6	do	5	80	
18		Fort Washington Heights	300	8	do		10	Abandoned.
19	Mr. McGuire	1 mile N. of Shiremanstown	120	6	do	30	30	
20	D. B. Meals	do	120	6	do		30	40 feet of casing.
21	Davis Farm	1½ miles SW. of Mechanicsburg	300	6	Beekmantown limestone		1	
22	Coover Farm	1 mile W. of Mechanicsburg	600	6	do		2	Water was obtained in first 100 feet.
23	John Ritter Farm	½ mile S. of New Kingstown	250±	6	do		30	Small drawdown.
24		½ mile NE. of Carlisle	600	8	do			Dense limestone; intended for cesspool.
25	Mr. Eschelman	New Kingstown	80	6	Stones River limestone		10	
26	H. B. McCormick Estate	2 miles N. of Mechanicsburg	577	6	Martinsburg shale and Stones River limestone	120	30	
27	Mt. Holly Paper Mills	Mt. Holly Springs	300	6	Weverton sandstone		Large	Cased through shale and sand 180 feet.

28	Mt. Holly Clay Corp.	do	250	8	Tomstown dolomite		100	Abandoned.
29	Mt. Holly Spgs. Clay Works	do	360	8	do		70	Some clay; cased to 240 feet.
30	Farmers on Route 11	West of Hogestown	60-300	6	Stones River limestone		5-25	
31	United States Army	Carlisle Barracks	60	6	Beekmantown limestone		50	Water in openings.
32	Clarence A. Strohm	½ mile S. of Lees Cross Roads	120	6	Tomstown dolomite	100	5	See analysis.
33	Milk Depot (burned)	Lees Cross Roads	170	6	do		15	
34	L. J. Highlands	do	110	72	do		8	Dug well 6 feet in diameter.
35	George Brown	1½ miles N. of Newville	76	6	Martinsburg shale	15	3	See analysis.

GENERAL CONDITIONS

Less than half of Dauphin County is in the area covered by this report. Unlike most of the counties to the east, Dauphin does not end at the crest of Blue or First Mountain but extends a number of miles northward and includes a large area of the Appalachian ridges. The total area of the county is 522 square miles, but less than 250 square miles lies south of Blue or First Mountain. These 250 square miles, however, include the more populous sections of the county—the city of Harrisburg, the capital of Pennsylvania; Steelton, with its steel mills, and a number of other towns and villages. The population of Harrisburg, according to the United States Census of 1930 is 80,339, and of Steelton, 13,291.

Harrisburg and Steelton obtain their water supplies from Susquehanna River which forms the western boundary of the county, and Middletown obtains its supply from a tributary of Swatara Creek. Surface streams supply most of the inhabitants of the area under discussion, but in most of the smaller towns and villages and on the farms, ground water or cisterns to store rain water are the only sources of supply.

GEOLOGY OF DAUPHIN COUNTY

Geologic column for south half of Dauphin County

Age	Name and description	Thickness	Water-bearing properties
Triassic	Diabase. Fine to medium-grained crystalline rock.	?	A poor water-bearing formation.
	Gettysburg shale. Soft red shale and sandstone with some harder gray sandstones. In part baked and altered by igneous intrusions.	9000	A fairly good water-bearing formation. Few wells are failures, but most wells yield small supplies. The baked and altered rocks are more impervious and are poorer aquifers.
Upper Ordovician	Juniata formation. Soft red sandstone and hard white conglomerate.	68	Unimportant as a source of ground water.
Upper and Middle Ordovician	Martinsburg shale. Soft gray, yellow, blue and black shales, dark calcareous shale, thin limestone.	2000+	A poor water-bearing formation. Most wells yield small supplies of hard water.
Lower Ordovician	Leesport "cement rock", a dense argillaceous limestone.	200±	Limestones are imperious but solution channels may contain large volumes of water. The yield of wells depends upon the wells intersecting water-bearing channels. The calcareous shales are less promising aquifers.
	Stones River limestone. Pure, thin-bedded, even-grained, dove-colored limestone with some magnesian layers.	500+	
	Beekmantown limestone. Thick-bedded, rather pure, gray limestone, laminated magnesian limestone, "edgewise" conglomerate.	2000±	
Upper Cambrian	Conococheague limestone. Thin-bedded, blue limestone finely banded with siliceous laminae.	100±	

[1] The data for this column were compiled from the following publications: Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg folio No. 170, 1909.
Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio, No. 225, page 22, 1909.
Jonas, A. I. and Stose, G. W., Top. and Geol. Atlas of Pa., No. 168, Lancaster Quadrangle, page 16, figure 2, 1930.
Stose, G. W., Unconformity at the base of the Silurian in southeastern Pennsylvania: Bull. Geol. Soc. Am. vol. 41, pp. 638-641, 1930.
Stose, G. W. and Jonas, A. I., Geology and mineral resources of the Middletown quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, pp. 86, 1933.

The above mentioned formations are described and their water-bearing properties are discussed in the introductory part of this report.

The Elbrook limestone may be present in this county but has not been definitely recognized.[1]

TOWNSHIP DESCRIPTIONS

East, West, and South Hanover townships. The only formation outcropping in the parts of these townships included in this report is the Martinsburg shale, which usually yields small supplies.

Derry, Londonderry, and Conewago townships. The oldest formations outcropping in these townships are the Beekmantown and Stones River limestones which underlie the valley. Wells in these limestones usually yield small supplies (Nos. 4 and 5). The limestones are overlain by the Leesport "cement rock" and the Martinsburg shale. Most wells in the shale will not overflow, but the water is frequently under sufficient head to rise a number of feet in the well (No. 7).

The limestones are overlain unconformably by Gettysburg shale in the southern part of the area. While adequate data are lacking in this area, results of well drilling in adjacent areas indicate that small supplies can usually be obtained and in places industrial and municipal supplies are obtainable. At Royalton an 80-foot well at the Nelson meat packing plant gives 60 g.p.m.; on the other hand, a well on the Hollinger farm on the east line of Conewago Township was dry at 600 feet. The diabase in these townships makes ridges that are strewn with residual boulders and left in timber. Small supplies of water may be obtained at the contact where a considerable thickness of weathered rock rests on fresh diabase.

Susquehanna and Lower Paxton townships. The only formations outcropping in these townships south of Blue Mountain are the Martinsburg shale and the Juniata formation. The latter is unimportant as a source of ground water. The former is not a good aquifer but wells in it show that small supplies and, in some cases, adequate industrial supplies, are usually obtainable. (Nos. 10 to 29.) Wells Nos. 8, 9, 17-29 in Harrisburg are all in the Martinsburg shale, range in depth from 150 to 1,320 feet and yield 10 to 120 gallons a minute. These 15 deep wells in Harrisburg reported by the writer, and several others recorded since this report was written, indicate rather clearly the futility of drilling more than 400 or 500 feet in the Martinsburg shale. Below that depth the chance of getting water is so meager that if the first hole is dry or the yield is inadequate, it is much better to drill another hole than to further deepen the first one. This point is illustrated by wells of the Hershey Creamery Co. and Russ Brothers. Well 24a in the following table is 1320 feet deep, but the 20 gallons which it yields enter at 455 feet. The lower 800 feet did not increase the yield. An adjacent well, 24b, 500 feet deep yields 65 gallons. Russ Brothers drilled a 1206-foot well which yielded 10 gallons at shallow depth and was dry below 88 feet, but 150 feet away, a second well 100 feet deep yields 30 gallons. Likewise, the 800-foot well at the State Theater is reported to have gotten most of its water within 300 feet of the surface. The

[1] Stose, G. W., Personal communication.

bottom 200 feet is in very hard sandstone. Only those wells near the contact of the shale and the underlying limestones are favorably situated for the drillers to attempt to develop supplies from the limestone.

Swatara and Lower Swatara townships. The oldest formation which outcrops in these townships is the Conococheague limestone and it is overlain by the Beekmantown and the Stones River limestones. (No. 32). A number of wells have been drilled in Paxtang and Rutherford, but they are now abandoned or used for cesspools, and little information concerning them is available. No large wells have been reported in the limestone in these townships, but any well may encounter large water-bearing solution channels and yield a large volume of water. Several years ago blasting in the bottom of a limestone quarry at Paxtang broke into a water channel which discharged so profusely that the operator had difficulty in rescuing tools from the quarry floor before it was flooded. The quarry was abandoned because of the water. The limestones are overlain by the Martinsburg shale, which can usually be depended upon for small supplies, or are overlain unconformably by the Gettysburg shale. The results of drilling indicate that fairly large supplies can be obtained from the Triassic rocks (Nos. 33 to 35 and Nos. 36 to 39).

Since the field work for this report was done several deep wells have been drilled east of Highspire. The first of these was for C. C. Cumbler at the sand plant on the edge of the village. It is 200 feet deep in the bottom of a 25-foot shaft. Rock was reached at less than 50 feet, and the first water was found about 20 feet in red shale. On test the well yielded 200 g.p.m. for 4 hours with a drawdown of only 3 feet. The Mumma sand plant 1 mile east of Highspire on the gravel terrace along the railroad has two deep wells which pass through about 40 feet of gravel and enter red sandstone and shale. A 10-inch well 700 feet deep is cased through the gravel. Water enters at 100 feet or more and rises within 20 feet of the surface. A turbine pump set 200 feet below the surface delivers 450 g.p.m. with a drawdown of 120 feet, but the well fills within a few moments after the pump stops. Another well 400 feet away is 500 feet deep and gets 200 g.p.m.

The Whittock sand and gravel plant 1,000 feet farther east and 500 feet east of White Horse lane, has a well 700 feet from the river and about 20 feet above it, which is 120 feet deep in Gettysburg shale and yields 250 g.p.m. It has not been tested for capacity. The well was dry to 110 feet, all water entering at the bottom.

Another notable well is that of the water company at Middletown. It was sunk through red Triassic sediments. "Granite" or diabase was struck at 415 feet and drilled into about 30 feet. Water enters at 110 feet and below, but especially in soft shale at about 400 feet, and fills the well to 16 feet from the surface. A 6-inch turbine discharging 600 g.p.m. draws the well down 90 feet but it fills again in two hours. The driller's test for capacity showed over 700 gallons.

DRILLED WELLS IN DAUPHIN COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1		Manada Hill to Grantsville	80–100		Martinsburg shale		10±	Numerous wells.
2		Manada Hill to Union Deposit	80–100		do		2–10	40 wells, similar.
3		Hoernerstown	80–150	6	do		5	Several wells.
4		Hockersville	100–120	6	Beckmantown limestone		10	6 wells.
5	Swatara Hotel	Swatara	160	6	Stones River limestone		10	Cased 100 feet; broken limestone.
7	I. Moyer	1½ mile NE. of Derry	500	8	Martinsburg shale		3	Flows.
8	Harrisburg Gas Co.	Harrisburg	170	8	Stones River limestone		100	Water in 3′ hole at 165′.
9	Dean F. Walker	409 N. 2d St., Harrisburg	150	8	Martinsburg shale		30	
10	Ebersole's Garage	Linglestown	125	6	do		20	
11		Old Linglestown Road	60–100	6	do		2–20	20 wells.
12		Cox Island, Harrisburg	100	6	do			Small yield.
13		do	80	6	do	20	15	
14		do	60	6	do			Small yield.
15		From Progress to Linglestown	100	6	do		2–10	Numerous wells.
16	Schoops Church	½ mile NW. of Progress	150	6	do	30	30	
17	Fink's Brewery	920 Capitol St., Harrisburg	300	8	do	30	20	
18	do	do	465	8	do		70	200 feet from No. 17.
19	do	do	300	8	do		15	100 feet from No. 17.
20	Pennsylvania Milk Products Co.	Atlas Ave., Harrisburg	600	10	do		90	Cooling.
21	Penn Harris Hotel	Harrisburg	300	8	do		75	do
22	Governor Hotel	do	150	6	do		25	do
23a	Harrisburg Light & Power Co.	10th & Market Sts., Harrisburg	200	8	do		120	Boiler use.
23b	do	do	200	8	do		60	
23c	do	do	200	8	do		60	
24a	Hershey Creamery Co.	Harrisburg	1,320	8	do	25	20	Water enters at 465 feet.
24b	do	do	500	8	do		65	
25	Merchants Ice Co.	do	600	10	do		30	Abandoned.
26	Keystone Chocolate Co.	do	125	6	do		10	
27	United Ice and Coal Co.	Cowden St., Harrisburg	300	8	do		50	Cooling; 8 wells, 2 of which are pumped.
28	do	13th & Howard Sts., Harrisburg	800	6	do		50	
29	Russ Brothers	19th St. & Reading RR., Harrisburg	1,206		do		10	Dry below 88 feet; shale at 700 feet.
		do	100		do		30	150 feet from No. 29.
32	Ebenezer District School	2 miles N. of Highspire	65	6	Beckmantown limestone		5	

33	Post Office	Oberlin	238	6	Martinsburg shale	125	¼	Water enters at 140 feet.
34	National Brewing Co.	Steelton	250	8	do		80	32 feet of casing.
35	Butcher Shop	do	300	6	do		10	30 feet of casing.
36		Highspire	60–80	6	Gettysburg shale		15–20	
37	Keystone Carbonic Gas Co.	do	200	8	do		100	Water encountered in first 100 feet.
38	Bethlehem Steel Co.	Steelton	250–400	8	do		75	7 wells; 75 gallons each. Coke plant.
39	Middletown Ice Co.	Middletown	300	8	do		80	
	Middletown & Royalton Water Co	Middletown	445	8	do	16	600	Drawdown 90 feet.
	C. T. Nelson meat plant	Royalton	80	5⅝	do	20	60	
	Walter M. Mumma sand plant	Highspire	700	10	do	20	450	Drawdown 120 feet.
	do	do	500	8	do	20	200	
	Whittock sand plant	do	120	6	do	20	250+	Dry to 110 feet.
	Highspire Sand & Gravel Co.	do	225	6	do	20	200	Drawdown 3 feet.
	Velruss Ice Cream Co.	Harrisburg	100	8	Martinsburg shale		50	Lower 300 feet in sandstone (?).
	Harrisburger Hotel	do	60	6	do		50	
	State Theater	do	800	6	do		75	Water in first 300 feet.
	Alva Restaurant	do	411	6	do		12	
	East End Dairy	do	496	6	do		37	12 g.p.m. in last 90 feet in limestone.
	Graupner Brewery	do	400	8–6	do	20	170	Drawdown 120 feet.

DELAWARE COUNTY

GENERAL CONDITIONS

Delaware County has an area of 185 square miles and is situated in the southeastern corner of the State. The county borders on Delaware River, which forms the boundary between Pennsylvania and New Jersey. The total population, according to the United States Census of 1930, is 280,264, including Chester, the largest city, with 59,164 inhabitants, and Media, the county seat, with 5,372 inhabitants. The average number of inhabitants per square mile is 1514.9, or approximately seven times the density of the entire State. The townships bordering on Delaware River are highly developed industrially, while those adjacent to Philadelphia are essentially suburban residential areas with industry of subordinate importance. The remainder of the county is rural, with numerous small towns and villages. There are 689 farms in the county, according to the same census.

The eastern and southern parts of the county are thickly settled, and water systems, chiefly privately owned, supply the area. The water companies draw practically their entire supply from surface streams, and the water is filtered and chlorinated before distribution. Some wells are still maintained for reserve supplies. The Springfield Consolidated Water Co. and its allied interests supply a large area[1] in this county. Media has a municipal supply obtained from Ridley Creek. This system also supplies Moylan and Wallingford villages. Chester, South Chester, and Marcus Hook are supplied by a private company with water taken from Delaware River.

Wells in the areas supplied by the water companies are largely abandoned and little information concerning them was available. Some new wells have been drilled for industrial use, but the yields have not been large enough, in most instances, to encourage many other companies to drill wells. Where new land developments are made near the areas served by the water companies, the mains are extended, which makes the drilling of wells unnecessary. Where the developments are too far from existing systems it has been common to drill a well for each house because it is usually difficult to obtain single wells with sufficiently large yield to supply a community. In areas adjacent to the water systems an individual owner frequently must decide whether it is more advantageous to spend his money for a connection with the water system or for a well and pump with a pressure system.

Springs are still used as a source of water supply on many of the older farms. Most springs in the area have small yields and some of them are much reduced in yield during prolonged droughts, but a great majority never go completely dry. Dug wells were formerly in common use but are being gradually abandoned for drilled wells. Many of them were not sunk far below the zone of fluctuation of the water table and consequently went dry in severe droughts.

---

[1] Water Supply Commission of Pennsylvania, Waters Resources Inventory Report, Part VI, Water Supply, pp. 256–263, Harrisburg, 1920.

GEOLOGY OF DELAWARE COUNTY

This county lies largely within the Piedmont Province. The coastal plain deposits rest unconformably upon the crystalline rocks along Delaware River. The following geologic column is inserted at this point for the convenience of the user of this section of the report.

Geologic section for Delaware County[1]

SEDIMENTARY ROCKS

Age	Name and description	Water-bearing properties
Pleistocene	Talbot formation. Sand, gravel, and clay.	In most places too thin to be an important source of water.
	Wicomico formation. Sand, gravel, and clay.	do
	Sunderland formation. Sand, gravel, and clay.	do
	Brandywine gravel.	Yields small supplies and in some place large supplies.
Tertiary (?) (Pliocene?)	Bryn Mawr gravel.	do
Algonkian	Wissahickon formation. Mica schist and gneiss.	do
Archean	Baltimore gneiss. Banded gneiss.	do

IGNEOUS ROCKS

Triassic	Diabase. Dark-grained crystalline rock.	Poor water horizon
	Gabbro. Dark, coarse-grained crystalline.	Very poor water horizon
Pre-Cambrian	Granite. Granite gneiss and similar rocks. Light to dark crystalline rock frequently gneissoid.	Poor water horizon
	Serpentine. Soft, green, chemically inert rock	Poor water horizon

[1] Bascom, F., and others, U. S. Geol. Survey Geologic Atlas, Philadelphia, Pa.-N. J.-Del. folio (No. 162), 1909.

The formations named above are described on pages 18-38, 65-69 .

TOWNSHIP DESCRIPTIONS

Haverford Township. The oldest rock outcropping in the township is the Wissahickon formation of schist and gneiss, which is at the surface over a large area. This rock is a fairly good horizon for small supplies and in some places yields large supplies. The Barrett Ice Plant[1] in Bryn Mawr has two wells; one is 752 feet deep and yields 10 gallons a minute, the other is 475 feet deep and yields 60 gallons a minute. The Bryn Mawr Hospital has a well, 135 feet deep, which yields 5 gallons a minute; the Bryn Mawr Hotel has a 10-inch well, 350 feet deep, which yields 50 gallons a minute. The well of A. S. Hall (No. 1) is approximately 100 feet deep and yields 3 gallons a minute. Granite gneiss and gabbro are found in a small part of the township. They are in general poorer water horizons than the Wissahickon formation.

The uplands in the vicinity of Bryn Mawr and Grassland are covered with terrace deposits of sand and gravel, the depth of which does not exceed 20 feet and is normally much less. The terrace in the vicinity

[1] Bascom, F., and others, U. S. Geol. Survey Geological Atlas, Philadelphia, Pa.—N. J.—Del. Folio (No. 162), p. 22, 1909.

of Bryn Mawr is older than the one at Grassland, and is called the Bryn Mawr terrace. The one at Grassland is the Brandywine terrace. Neither terrace deposit is an important source of water although dug wells are successful in the vicinity of Grassland.

Upper Darby Township. Upper Darby Township is almost completely suburbanized, and the residents are served by water companies which derive their supplies from surface waters. Granite and gabbro are present in the township, and only small supplies can usually be obtained from them.

Darby, Ridley and Tinicum Townships. The Wissahickon formation and the granite gneiss occur in these townships but are covered with a layer of terrace gravel except where the streams have cut down into them. A well in the granite gneiss at Clifton Heights is only 30 feet deep and yields 100 gallons a minute, but as a rule this formation will yield only small supplies. The conditions in Ridley Township are similar to those in Darby Township. Much of Tinicum Township is a marsh.

Radnor Township. The oldest formation outcropping in Radnor Township is Baltimore gneiss, which is at the surface over a large area. Some wells in this rock indicate that considerable water is available. A well at Wayne, 150 feet deep, yields 200 gallons a minute but this is an unusually productive well for the Baltimore gneiss. Gabbro, which underlies a large part of this township, is usually a poor water horizon. However, the 1,000-foot well of the Pennsylvania Railroad Co. at Radnor (No. 2), is in gabbro and yields 60 gallons a minute, the water being used for locomotives. Most of the water is probably obtained in the first 300 feet. The Wissahickon formation is found in the northern part of the township and can usually be depended on to furnish small supplies. The well of Adolph G. Rosengarten (No. 2a) yields 20 gallons per minute, with a 150-foot drawdown. This well is better than the average of wells drilled in this rock. The southern part of the township is underlain by serpentine and related rocks. Serpentine is an uncertain water horizon and yields water of poor quality.

Marple Township. The Wissahickon formation outcrops over the entire township except in a small area in the northwestern part, where serpentine is at the surface, and on the high divide between Darby and Crum creeks, where the Wissahickon formation is covered by a thin layer of the upper terrace deposits of sand and gravel. The Wissahickon formation is a fairly good water horizon, and little difficulty should be experienced in obtaining domestic supplies from it. (See wells Nos. 3 to 5.) The serpentine is a poor water horizon. Some water may be obtained by dug wells from the terrace deposits, but they are too thin to yield much water.

Springfield Township. Springfield Township is rather thickly inhabited and is for the most part supplied by water companies. The Wissahickon formation underlies most of the western half of the township and the granite gneiss the eastern half.

Newtown Township. The rock exposed in the middle of Newtown Township is the Baltimore gneiss, which supplies a number of drilled

wells in or near Newtown Square. (See Nos. 6 to 17.) The Wissahickon formation is at the surface in only a small area. Well No. 2 of the Pennsylvania Hospital for the Insane (No. 6b in the table), which is 300 feet deep and yields 30 gallons a minute, is in this formation. Well No. 3 of this hospital (No. 6c in the table), which is 323 feet deep and yields 70 gallons a minute, ends in serpentine. This yield is larger than is usually obtained from the serpentine in Delaware County. Gabbro occurring as an intrusion in the gneiss underlies half the township. The table contains records of a number of wells in this rock (Nos. 19 and 19a).

Upper Providence Township. Media, the seat of Delaware County, obtains its water supply from Ridley Creek. The Wissahickon formation is at the surface over most of the township and is the best source of ground water. (See wells Nos. 18, 20, and 21.) Serpentine and gabbro both outcrop in this township. In the vicinity of Media the Wissahickon formation is overlain by a thin covering of gravel, but it is not important as a source of water.

Nether Providence Township. The Wissahickon formation is found in the northern half of Nether Providence Township. The southern half of the township is largely covered by Wicomico terrace deposits, which in some places rest on granite gneiss. The Wissahickon formation, as shown by the wells in Upper Providence Township, can be depended on to furnish small supplies; granite gneiss is somewhat less favorable. The sands and gravels on the terrace are too thin to be of much importance as a source of water.

Chester Township. The city of Chester, which obtains its water supply from the Delaware River, will be treated as part of Chester Township. The Wissahickon formation is the oldest formation exposed in the township. (See wells Nos. 22, 23, and 26.) Except in the northern part it is overlain by deposits of the Wicomico and Talbot terraces. The granite gneiss underlies the terrace deposits in the southern part of the township. Several wells have penetrated this rock, but the yields, except in one instance, have not been large. (See Nos. 24, 25, 27, and 28.) The formation does not offer much encouragement as a source of industrial supplies. The Wissahickon formation has been intruded by a long dike of hornblende gneiss. A well in this rock, near Bridgewater (No. 29), is 65 feet deep and yields 5 gallons a minute. The terrace deposits, consisting chiefly of sand and gravel, are generally too thin to yield much water. However, locally they are thicker and are favorable water horizons. The well of Simpson and Sons (No. 30) is close to Delaware River and is drilled into the gravel of the Talbot terrace. It is only 22 feet deep but yields more than 50 gallons a minute. The other wells drilled in Chester passed through these sands and gravels without finding much water.

Edgemont Township. The Baltimore gneiss is the oldest formation outcropping in Edgemont Township. A number of wells have been drilled in this gneiss at Florida Park (Nos. 31 to 37). Gabbro occurs as an intrusion in the Baltimore gneiss. A small area of serpentine occurs in the northeastern part of the township.

Middletown Township. The Wissahickon formation underlies most of the township, but a broad belt of gabbro crosses it with a northeast-southwest trend, and in the extreme southern part of the township the Wissahickon is overlain by terrace deposits.

Numerous wells have been drilled in the Wissahickon formation (See Nos. 51 to 59). Six drilled wells at Chester Heights (Nos. 54 to 59) range in depth from 50 to 133 feet and in yield from 4 to 30 gallons a minute.

Many wells have also been drilled into the gabbro (Nos. 60 to 92). A number of wells have been drilled in Rockdale and on the hills above the village. They range from 30 to 100 feet in depth, and with two exceptions (Nos. 68 and 69), all yield less than 5 gallons a minute. About 20 wells have been drilled in the vicinity of Llewellyn Mills which range in depth from about 30 to 100 feet, and generally yield from 1 to 10 gallons a minute (Nos. 71 to 83). The Wicomico terrace deposits, consisting of sand and gravel, are too thin to be an important source of water.

Upper Chichester Township. Gabbro is the dominant formation in Upper Chichester Township and the principal source of ground water (See Nos. 93 to 100).

The Wicomico terrace deposits are thick enough in some places to furnish considerable water. The School House well at Ogden (No. 101) is 72 feet deep and yields 30 gallons a minute. The supply is obtained from gravel in the first 30 or 40 feet. At Twin Oaks five wells have been drilled that average 45 feet deep and yield 25 gallons a minute each. These wells are located in places where the sand and gravel are relatively thick and contain considerable volumes of water.

Chichester Township. The rock is almost everywhere concealed in Chichester Township beneath deposits of the Talbot and Wicomico terraces. Except locally, these deposits do not yield even small supplies and in general one must drill into underlying rocks to get water. As revealed by outcrops along the streams, the terrace deposits are underlain by gabbro except in a small area where the Wissahickon formation occurs. The well of the Linden Thorpe Inn, Marcus Hook (No. 103), is 156 feet deep and yields 7 gallons a minute. The well of the Linoleum Co. (No. 104) is 1,825 feet deep and is a failure.

Thornbury Township. The formations outcropping in Thornbury Township are the Baltimore gneiss and the gabbro. Wells drilled into these rocks usually yield small supplies but there are some failures, especially in gabbro. For examples of wells in this township see Nos. 105 to 108.

Concord Township. The Wissahickon formation is the oldest rock outcropping in Concord Township, and is the most favorable formation for water supply. It is somewhat more schistose in this township than in the northeastern part of the county. A number of successful wells have been drilled into it. Several wells with small yield have also been drilled in the gabbro in this township (See Nos. 124 to 131).

Serpentine is found in several isolated patches. In one of these near Elam is the well of the Methodist Church (No. 132), which is 85 feet

deep and yields 7 gallons a minute of water that is not highly mineralized, as is shown by the analysis.

Bethel Township. Gabbro is at the surface over most of Bethel Township. The Wissahickon formation outcrops in a few places but is not important as a source of water except in the vicinity of Chelsea. The records of wells in this township given in the table (Nos. 133 to 141) show that drilled wells in gabbro usually yield small supplies of good water at moderate depths.

Birmingham Township. The principal rocks outcropping in Birmingham Township are the Baltimore gneiss and the Wissahickon formation which are fairly good water horizons, although the yields of the wells in them are generally small. The yields of the three wells (Nos. 142 to 144) in Baltimore gneiss, given in the table, are doubtless above the average for wells in this rock.

For wells drilled into the Wissahickon formation see Nos. 145 to 148 in the table.

Gabbro and serpentine both outcrop in the township, but the serpentine areas are much smaller in extent than the gabbro areas. Both of these rocks are somewhat poorer water horizons than the Baltimore gneiss and the Wissahickon formation and not all wells drilled into them are successful.

DRILLED WELLS IN DELAWARE COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1	A. S. Hall	Llanerch	100	6	Wissahickon		3	
2	Pennsylvania Railroad Co.	Radnor	1,000	12	Gabbro		60	Air lift
2a	Adolph G. Rosengarten	1 mile S. of Wayne	200	8	do	50	20	Drawdown 150 feet
3	John Sonders	Broomal	70	6	Wissahickon		30	
4	James Downs	do	60	5⅝	do		6	
5	William Aigeo	Marple	50	6	do		8	
6a	Pennsylvania Hospital for Insane Well No. 1	1 mile NE. of Newtown Square	380	8	Baltimore gneiss		32	Drawdown 105 feet
6b	No. 2	do	300	8	Wissahickon		30	
6c	No. 3	do	323	8	Serpentine		70	
7	William Prickles	Newtown Square	57	6	Baltimore gneiss		8	
8	Antone Hutton	Near Newtown Square	116	6	do	15	8	
9	C. P. Shaw	do	100	6	do	28	5	
10	H. H. Matson	Newtown Square	70	6	do	22	18	Drawdown 28 feet
11	Father William Maguire	do	108	6	do	37	30	
12	E. M. G. Davis	do	111	6	do	12	10	
13	do	do	72	6	do	15	15	
14	Thomas H. Yarnall	do	100	6	do	10	4	
15	R. P. Dutton	do	150	6	do		10	
16	L. K. Tomlinson	do	100	6	do		10	
17	Henry Forsythe	do	110	6	do	19	20	Drawdown 20 feet
18	Roman Catholic Cemetery	Rosetree	60	5⅝	Wissahickon		15	
19	Clarke Thompson	1½ mile SW. of Newtown Square	475	6?	Gabbro		2	
19a	do	do	210	6?	do		½	
20	G. W. Reid	Media	89	6	Wissahickon	37	10	
21	W. L. Cloud	do	68	6	do	24	10	
22	Herman Leader	Upland	35	5⅝	do		15	
23	J. Trainer	Chester	45	5⅝	do		5	Drilled through overlying terrace deposits
24	Sun Shipbuilding Co.	do	152	8	Granite			Yield small but not tested
25	Manufacturers Paraffine Co.	do	200	8	do	20	75	
26	B. Baxter	do	303	5⅝	Wissahickon		4	Large drawdown
27	James C. Beaumont	do	112	6	Granite		5	
28	Troy Laundry	do	400	8	do	15	2	
29		Near Bridgewater	65	5⅝	Gneiss	40	5	
30	Simpson & Sons	Chester	22	5⅝	Terrace deposits		50+	Gravel
31	George Shaloes	Florida Park	65	6	Baltimore gneiss	22	7	
32	Charles Kopp	do	51	6	do	20	7	

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
33	Mrs. Emma Schroeder	Florida Park	66	6	Baltimore gneiss	5	30	
34	William Prickles	do	73	6	do	45	3	
35	Francisco Panzullo	do	59	6	do		10	Dug 37 feet
36	Frank Hogan	do	44	6	do	34	15	
37	Cole Piersol	do	170	6	do	22	4	
38	George Wood	Wawa	300		Wissahickon		30	
39a	L. W. Weischedel	1 mile NE. of Glen Riddle	85	6	do		15	
39b	do	do	85	6	do		15	100 feet distant from No. 39a
40	Mrs. S. C. Riddle	Glen Riddle	93	6	do		50	
41	do	do	323	6	do (?)		10	
42	do	do	50	6	do		3.5	
43	Pennsylvania Railroad Co.	do	204	6	do		4	
44	Ed Sheldon	¼ mile N. of Lenni Mills	64	6	Gabbro		3	
45	Amos Johnson	Near Lima	58	6	Serpentine		2	Weathered rock
46	Harvey Moyer	Near Lima	103	6	Serpentine			Only 3 gallons an hour
47	Penrose Worrell	Lima	56	6	do	8	8	
48	Rush Super	do	58	6	do	5	8	48 feet to rock; drawdown 32 feet
49		do	89	6	do	12	4	Large drawdown
50	J. R. Litzenberg	Near Lima	200±	6	do		9	
51	James Harper	Village Green	75	6	Wissahickon		28	Water enters at 35 feet; see analysis
52	do	do	78	6	do		28	Water enters at 35 feet
53	Frank Scott	¾ mile SW. of Lenni Mills	62	6	do		2½	
54	Chester Heights Camp Asso.	Chester Heights	133	6	do		4	
55	Burchnell and Dinster	do	75	6	do		30	
56	Miss L. Fury	do	65	6	do		6	
57	Richard & Schader	do	50	6	do		8	
58	do	do	70	6	do		5	
59	Townsend & Moore	do	54	6	Granite		7	
60	Yorkshire Mills	Lenni Mills	58	6	Gabbro		1½	Used by 18 families
61	Fred Cole	do	47	6	do	10	10	
62	J. Hayes	Glen Riddle	150	5⅝	do		4	Hard rock near quarry
62a	M. L. Donovan	Near Lenni Mills	80	6	do		8	
63	George Wood	Near Wawa	25	5⅝	do		6	Average of 5 wells
64	do	do	72	6	do		22	Water from disintegrated material
65	do	do	63	6	do		65	Blue rock
66	do	do	300	6	do		25	
67	Edward Worth	do	27	5⅝	do	15	4	Windmill
68		Crozierville	35	6	do		20	
69	Atwood Steward	Rockdale	30	6	do		10	

70	L. M. Ford	do	40	6	do		4	Polluted
71	M. Bunker	Near Llewellyn Mills	50	6	do		25	Feldspar and kaolin
72	Mrs. E. Smith	do	73	6	do		6	
73	James Melio	do	50	6	do		1½	Decayed rock
74	Alkin Stark	do	49	6	do		1½	
75	H. Loughead	do	57	6	do		1½	
76	J. Quimby	do	103	6	do		4	
77	J. McKewoen	do	55	6	do		1½	
78	Mrs. Blair	do	43	6	do		1½	
79	A. Green	do	54	6	do		2	
80	Frank Ogden	do	85	6	do		2	Weathered rock
81	John Z. Hunter	do	30	6	do		4	
82	Mrs. Evans	do	72	6	do		7	Water in decayed layer
83	Elwood Smith	do	61	6	do		3	Mica rock
84	Convent		60-80	5⅝	do		8-10	5 wells
85	Joseph Elliott	Rockdale	40	6	do		2	
86	Harry Tilghman	Crozierville	98	6	do		3	
87	Mrs. Preston	Near Rockdale	100	6	do		1	Gray
88	Grover Springer	do	48	6	do		3	Decayed rock
89	Robert Ornsly	do	60	6	do		1	Blue rock
90		do	60	6	do		3	Pink boulders
91	Tiny Schibert	do	60	6	do		2	
92	Alfred Bryant	do	49	6	do		3	Blue rock
93	George Hance	Hance	60	5⅝	do		5	
94	John Ogden	do	60	5⅝	do		5	Another well, 50 feet deep, yields 5 g.p.m.
95	A. J. Hance & Sons	Boothwyn	71	6	do		25	Drawdown 35 feet
96	Elihue & Talley	do	102	6	do	20	18	
97	H. F. Brown	do	49	6	do		1	Wicomico terrace deposits to 19 feet: see analysis
98	H. F. Brown	Boothwyn	49	6	do		1	
99	do	do	49	6	do		1	
100	L. B. Cox	do	64	6	do	19	5	16¾ feet of 6-inch casing
101	School House	Ogden	72	6	Quaternary		30	Gravel
102		Twin Oaks	45	5⅝	Wissahickon		25	Sand; a number of wells
103	Linden Thorpe Inn	Marcus Hook	156	5⅝	do		7	
104	Linoleum Co.	do	1,825	6	do		0	
105	W. Lawson	Cheyney	50	6	Baltimore gneiss		10	
106	Horace Martin	Thornton	57	6	Gabbro		10	Rusty rock, jointed
107	Mrs. H. Yearley	do	84	6	do			Failure; less than 1 gallon an hour
108	Thornbury Church	[illegible] mile NE. of Thornbury	67	5⅝	do		8	
109	Alvin Harvey	[illegible] mile N. of Brandywine Summit	60	5⅝	Wissahickon		40	Encountered quartz vein from which much of the water is derived
110	Warren C. Walton	Brandywine Summit	51	6	do		30	See analysis
111	P. E. Sharpless Creamery Co.	½ mile E. of Ward	205	6	do		53	

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
112	Sharpless Creamery Co.	Ward	85	6	Wissahickon		4	Rusty rock
113	do	do	96	5⅝	do		48	
114	Jefferson Fulmer	do	50	6	do		5	
115	Samuel Hill	Markham	85	6	do		22	
116	Dr. Darlington	Concordville	60	5⅝	do		10	
117	do	do	50	5⅝	do		3	
118	Frank Rawlings	Elam	106	6	do		20	See analysis
119a	Talley Bungalow	do	75	6	do		18	
119b	Camp Meeting Grounds	do	80	5⅝	do		15	
120a		do	48	5⅝	do		100	
120b		do	50	5⅝	do		15	
120c		do	47	5⅝	do		50	
120d		do	50	6	do		15	
123	Ed. Hanway	do	85	5⅝	do		10	
123a		do	80	5⅝	do		15	
124	J. Hannum	Near Ward	52	6	Gabbro (?)		3	Blue, soft to hard
124a	Tony Fletcher	do	39	6	do		3	Blue rock
125	Walter Hibbert	do	72	6	do (?)		4	Garnet rock
126	Nelson Clayton	do	64	6	do		5	
127	John Marion	do	70	6	do		4	Garnet rock
128	Howard Hannum	do	70	6	do		3½	
129	T. Richards	¼ mile N. of Ward	65	6	do		10	Solid blue rock
130	Israel Scott	½ mile N. of Ward	70	6	do		6	All loose material
131	Howard Cloud	Near Concordville	101	6	do		½	Blue rock
132	Methodist Church	Elam	85	6	Serpentine		7	See analysis
133	William Hutton	Near Chelsea	106	6	Gabbro		2	Dug 59 feet
134	Robert Phillips	do	75	5⅝	do		4	Garnet rock
135	Mr. King	do	35	5⅝	do		4	
136	A. Heffenberg	1 mile SW. of Chelsea	47	6	do		2	
137	Merrill Farm	1¼ miles SW. of Chelsea	29	6	do		25	
138	George A. Zehley	Booth Corner	38	6	do		2	Blue rock; see analysis
139	Dr. T. Booth	do	115	6	do		2	do
140	do	do	106	6	do		2	
141	Mr. Cheyney	do	50?	6	do		3	
142	Chadds Ford Hotel	Chadds Ford	67	6	Baltimore gneiss		22	See analysis
143	Horace Quimby	do	32	6	do		15	
144	do	do	35	6	do		15	
145	Alvin Hawley	⅓ mile N. of Brandywine Summit	50	5⅝	Wissahickon		15	
146	William Pilkington	S. of Brandywine Summit	100	6	do		2	
147	Roman Catholic Church	Near Elam	42	5⅝	do			Flowed
148	Old Feldspar Quarry	do	110	6	do		15±	Pegmatite dike
149	William Bleakley	Chelsea	72	6	Gabbro	55	⅓	

FRANKLIN COUNTY

GENERAL CONDITIONS

Franklin County is the westernmost of the counties described in this report. The total area of the county is 751 square miles, and the population, according to the United States Census of 1930, is 65,010, or 86.6 to the square mile. The population is approximately 60 per cent rural. The number of farms in the county is 3,536. The county seat, Chambersburg, has a population of 13,788 according to the same census. This city and several of the largest boroughs use surface water supplies. The remainder of the inhabitants use water from springs and wells, except that some of the people depend on rain water stored in cisterns or supplement their ground-water supplies with cistern water. All water obtained from the limestone is hard although the amount of hardness varies from well to well and from spring to spring. Towns in the valley requiring large supplies of soft water should develop the springs and spring-fed streams in the mountains. People dwelling in the middle of the valley are dependent on rain water for soft water, but people dwelling along the foot of either North or South Mountain can develop small springs and pipe the water to their dwellings and barns, thus obtaining not only soft water but water under pressure. Most springs in the valley issue at elevations which do not permit gravity distribution, but rams and small water wheels rigged to pumps would save the cost of pumping. A water-wheel driven by the discharge of Fall Spring is shown in Plate 6, B, page 187.

GEOLOGY OF FRANKLIN COUNTY

Only two of the three belts of rocks mentioned on page 10 are present in Franklin County; the belt of Triassic rocks is missing. The following geologic column is inserted at this point for the convenience of the users of this report who are interested in the ground-water resources of this county.

Geologic column for Franklin County, to the top of the Ordovician system.[1]

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Upper Ordovician	Juniata formation. Soft red sandstone and shale with some harder sandstone and conglomerate.	400–450	Unimportant as a source of water
Upper and Middle Ordovician	Martinsburg shale. Soft green arkosic shale at top, black shale at bottom.	2,000	Wells usually yield small supplies of hard water at moderate depths.
Middle Ordovician	Chambersburg limestone. Thin-bedded, tough, dark limestone with irregular clay partings. Interbedded shale at top.	100–750	Somewhat poorer water horizon than the underlying limestone. Hard water.
Lower Ordovician	Stones River limestone. Very pure, thin-bedded, even grained limestone with some magnesian layers.	675–1,050	Some large springs and excellent wells. Solid limestone yields little water but wells striking water-bearing solution channels yield large volumes of water. Hard water.
	Beekmantown limestone. Thick-bedded, rather pure limestone, usually finely laminated. Contains "edgewise" conglomerate.	2,300	
Upper Cambrian	Conococheague limestone. Thin-bedded, blue limestone finely banded by thin, hard, siliceous, generally contorted laminae that weather in relief.	1,635	Not a good ground-water horizon, but wells encountering solution channels yield large supplies. Hard water.
Upper and Middle Cambrian	Elbrook formation. Gray to pale blue, shaly, limestone and calcareous, papery shale with some heavier limestone beds at base and thick-bedded siliceous limestone in middle.	3,000	Poor water horizon. Most wells yield small supplies. Hard water.
Middle(?) and Lower Cambrian	Waynesboro formation. Slabby, gray, calcareous sandstones or sandy limestones and hard, slaty, purple shale. Large white chert heads and vein quartz in lower part.	1,000±	Poor water horizon. Most wells yield small supplies. Hard water.
Lower Cambrian	Tomstown dolomite. Massive and thin-bedded dolomite, in part cherty and magnesian, with considerable shale and soft white clay at the base.	1,000±	Wells intersecting water-bearing solution channels yield large supplies but wells in solid limestone are frequently dry. Considerable ground water is available at contact with underlying Antietam sandstone. Hard water.
	Antietam quartzite. Coarse-grained, white, and bluish-gray quartzite and sandstone. Generally weathers to loose sand.	500–800	Fairly good water-bearing formation. Soft water.
	Harpers schist. Dar banded, tough, hackly schist or slate with massive, hard, white, scolithus-bearing quartzite (Montalto member) in middle.	2,750	Poor water horizon. Wells yield small supplies of soft water.
	Weverton sandstone. Coarse, gray, feldspathic sandstone and white, quartzose sandstone with purplish arkose and hard, purple, quartz conglomerate at the base.	1,250	Fairly good water-bearing horizon. Few wells in it. Springs yield soft water.
	Loudoun formation. Gray and purplish arkosic conglomerate and fine sericite slate.	550	A rather poor water-bearing formation which outcrops on thinly inhabited steep mountain slopes.
Algonkian	Metabasalt. Altered basalt lava. Massive to schistose greenstone.		Poor water horizon but supplies small springs of soft water.
	Aporhyolite. Altered rhyolite lava. Sericite schist at top.		do

[1] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

The formations mentioned above are described in the introductory part of this report.

TOWNSHIP DESCRIPTIONS

Lurgan, Southampton, and Greene townships. The oldest rocks outcropping in these townships are the pre-Cambrian volcanic rocks which come to the surface in South Mountain in the extreme southern part of Greene Township. A number of springs occur in the mountain, which is now part of the State Forest Reserve, and these furnish adequate supplies of excellent water for present needs. A spring in Caledonia Park flows about 10 gallons a minute (See analysis No. 26). This spring is inclosed in a concrete box and the water is piped to several houses and to the drinking fountains in the park. The ground around this spring has numerous fragments of quartzite and the spring may issue from talus. The swimming pool is fed by springs. Small supplies could also be obtained by drilling wells into these rocks.

The overlying Lower Cambrian rocks—Loudoun formation, Weverton sandstone, Harpers phyllite with the Montalto quartzite member, and Antietam quartzite—also outcrop in mountainous country that is largely uninhabited. Numerous small springs issue from these rocks and furnish water of excellent quality. The village of Fayetteville is supplied by gravity with soft water from Cold Spring Run, which is a small spring-fed stream. Other small springs issuing from these rocks could be improved and their water could be piped to the farms in the valley underlain by limestone.

The Antietam quartzite is overlain by formations consisting chiefly of limestone which underlies the valley area. Many small supplies are obtained from these formations and a few wells in them yield large supplies. The Tomstown dolomite forms a valley parallel to the front of South Mountain and in places is covered with talus. It gives rise to a number of springs. The Waynesboro formation is a relatively poor ground-water horizon and many people dwelling on this formation use rain water stored in cisterns. The rocks which seem to weather to sandstones are dense siliceous limestones in depth. The well of C. Burkholder (No. 1) is in limestone which apparently belongs to the Elbrook formation. The well of William Craig, Scotland (No. 2), is in the Conococheague limestone, which contains sandy layers, some of which were encountered in this well. The dug well of Charles S. Anderson, 3 miles northeast of Chambersburg (No. 3), is in the Beekmantown limestone, which is a relatively good ground-water horizon. The Beekmantown limestone is overlain by the Stones River limestone, the purest and probably the most cavernous of the limestones occurring in the Cumberland Valley, and this, in turn, is overlain by the Chambersburg limestone, which is more argillaceous. The Chambersburg limestone is overlain by the Martinsburg shale. Drilled wells are not common over the parts of Lurgan and Southampton townships where this shale is at the surface, but springs and dug wells, supplemented by cisterns, supply the needs of the inhabitants. The Martinsburg shale is overlain by younger rocks which are unimportant as a source of water in this area.

Guilford, Quincy, and Washington townships. The oldest rocks outcropping in these townships are volcanic rocks of pre-Cambrian age

which are not very promising ground-water horizons. A well drilled about 400 feet at the South Mountain Sanatorium yielded very little water. Seven springs used as part of the supply for the sanatorium show considerable fluctuation in flow. Monterey obtains its water supply from three drilled wells, 105, 119, and 120 feet deep, respectively, which are supplied from these rocks and together yield more than 25 gallons a minute.

The Loudoun formation rests unconformably upon the volcanic rocks of pre-Cambrian age and is not a good water-bearing formation. Few wells are drilled where it outcrops in thinly inhabited areas and on steep slopes which are usually strewn with debris from overlying quartzites. Some small springs issue from this formation.

The Weverton sandstone, which crowns most of the higher elevations of South Mountain and overlies the Loudoun formation, yields small supplies of excellent water. Blue Ridge Summit obtains its supply from two artesian wells in this formation, which have a combined flow of approximately 35 gallons a minute. These wells are situated in Maryland high on South Mountain. Two beautiful springs, named Pearl of the Park, and Tarburner Springs, issue from the Harpers schist close to the Weverton sandstone contact in State Forest Reserve. An analysis of the water from the former shows that the water is very soft. Buena Vista Springs, which also issue near the contact of the Weverton sandstone and the Harpers schist, are highly developed and form an important attraction at the large hotels. The Indian Spring, which issues from Antietam quartzite, flows about 10 gallons a minute of very clear water at a temperature of 49° F. (See analysis No. 28). Rouzersville obtains its water supply from springs issuing from the Antietam sandstone about 1 mile east of the borough. Part of this water is used in Pen Mar during the summer, but Pen Mar also obtains water from a spring at Mountain Lake cottage, three-fourths of a mile northwest of the village. Springs issuing from the Antietam quartzite are valuable to people living on the limestone because they furnish excellent soft water. The sandstone dips at such a steep angle that it is too far beneath the surface in the limestone area to develop water from it by drilling.

The Tomstown dolomite, which was named for its exposures at Tomstown in Quincy Township, forms a narrow valley parallel to the mountain. Drilled wells are not numerous in this valley, but dug wells, many of them old, are in use. Springs, some of them yielding as much as 100 gallons a minute, are numerous. Tomstown uses a spring about one-fourth of a mile north of the village as a public supply. Drilled wells in the Tomstown dolomite should yield small supplies although some wells may be failures. Wells encountering water-bearing solution channels may yield large supplies.

The Waynesboro formation, which takes its name from Waynesboro, in Washington Township, is apparently not a good water horizon and large yields are not to be expected. Cisterns are numerous in the area underlain by this formation and furnish the entire supply for many homes.

The Elbrook formation, which was named from the town of Elbrook, in Quincy Township, contains much shale and is not a good ground-water horizon. However, there are some soluble limestone beds which contain water, for some fairly large springs issue from this formation.

(See Plate 7-A). Several springs flow out from the rocks at Falling Spring, situated near a fault which has probably profoundly influenced the ground-water circulation in this vicinity. These springs form several pools and their combined flow, augmented by the springs at Aqua, make Falling Spring Branch. This branch was formerly a source of power to operate several mills. One of the group of springs composing Falling Spring has been inclosed and operates a small wheel which pumps water to a nearby farm house (See Plate 7-B). The water in the largest pool has a temperature of 48° F. (See analysis No. 30).

The Conococheague limestone supplies a number of wells (See Nos. 4 and 5). In the well of John Wishard (No. 4), an opening was encountered at 60 feet, but it was dry. The water which was struck near the bottom of the well rises to the opening and flows out through it.

The western part of Guilford Township is underlain by the Beekmantown limestone, the Stones River limestone, the Chambersburg limestone, and the Martinsburg shale (See wells Nos. 6 to 8).

Letterkenny, Hamilton, and St. Thomas townships. The formations outcropping in these townships range from the Beekmantown limestone to formations of Silurian age. The well of E. A. Ernst, 1½ miles west of St. Thomas (No. 9), is in the Beekmantown limestone.

In the Martinsburg shale dug wells ranging from 20 to 80 feet in depth are the most common means of obtaining water. In recent years some wells have been drilled into this shale, most of which yield small supplies (See Nos. 10 to 14). The Rocky Spring apparently issues from the sandy beds at the top of the Martinsburg shale. These sandy beds should be the best water horizon in the formation.

Peters, Montgomery, and Antrim townships. The formations exposed in these townships range from the Elbrook limestone, which comes to the surface in Antrim Township, upward to formations of Silurian age. The valley areas are underlain chiefly by limestones, which supply a number of wells. In this area the Beekmantown limestone seems to be unusually dense, for, with one exception, the wells in this formation listed in the table yield only very small supplies (See Nos. 15 to 23). The 18-foot well of H. E. Geiser (No. 22) is the only one that encountered cavernous limestone. Fort Loudon obtains its water supply from a spring that issues from the Stones River limestone three-fourths of a mile west of the village.

The well of Ira Eschelman, northwest of Kauffman (No. 24), is in the Chambersburg limestone. Although this limestone is shaly, well developed water-bearing solution channels were encountered in this well. The Martinsburg shale yields small supplies at relatively shallow depths. The well of the village of Upton (No. 25) is 30 feet deep and yields 3 gallons a minute. The spring of David Horn 3½ miles west of St. Thomas, yields 5 gallons a minute (See analysis No. 29). At Cove Gap a spring in the Juniata formation yielding 5 to 10 gallons a minute has been improved by W. A. Reitzel, and the water is piped to a fountain at the forks of the road at Foltz (See Plate 7-B and see analysis No. 31). In most places this formation is exposed high up on the flanks of the mountain, and is unimportant as a source of water.

Fannett, Metal, and Warren townships. These townships are chiefly in rugged country along the northwest margin of the county and are underlain in most parts by rocks of Silurian and Devonian age that were not studied in the present investigations.

DRILLED WELLS IN FRANKLIN COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1	C. Burkholder	2 miles NE. of Scotland	104	6	Elbrook limestone	30	4	
2	William Craig	Scotland	36	6	Conococheague limestone	14	3	
3	Charles S. Anderson	3 miles NE. of Chambersburg	40		Beekmantown limestone	34	5	Dug well about 3½ feet in diameter; small drawdown; see analysis.
4	John Wishard	2 miles W. of Waynesboro	103	6	Conococheague limestone		10	
5	Mr. Stuffey	2 miles W. of Waynesboro	65	6	do		4	
6	George Stinger	¼ mile S. of Chambersburg	75	6	Stones River limestone	25	2	
7	Harry Lesher	½ mile S. of Chambersburg	36	6	do	12	4	Cased nearly to bottom.
8		Guilford Springs	32	6	do		4	
9	E. A. Ernst	1½ miles W. of St. Thomas	86	6	Beekmantown limestone	76	2	
10	William Smith	½ mile W. of Chambersburg	43	6	Martinsburg shale	3	3	See analysis.
11	Kane's Lunch Stand	2½ miles E. of St. Thomas	55		do		2	
12	Mrs. Black	St. Thomas	86	6	do	8	2	See analysis.
13	do	do	50	6	do		2	
14	Mr. Harrison	do	65	6	do		2	
15	Antrim Township School	Kauffman	157	6	Beekmantown limestone		1	
16	do	do	194	6	do		1	Only 30 feet from No. 15.
17	Mr. Houck	3 miles SW. of St. Thomas	30		do		1	
18	Robert McDowell	½ mile N. of Lemaster	65	6	do		2	
19	Mr. Anderson	1¾ miles W. of Upton	63	6	do		1½	
20	John Neiswonger	do	36	6	do		3	
21	Paul Ullman	2 miles W. of Upton	75	6	do		1	
22	H. E. Geiser	3 miles SE. of Mercersburg	18	6	do	15	10	See analysis.
23	do	do	100		do			Close to No. 22; no water.
24	Ira Eschelman	1¾ miles NW. of Kauffman	51	6	Chambersburg limestone		15	
25	Town of Upton	Upton	30	6	Martinsburg shale	8	3	Small drawdown; opening 6 inches.

LANCASTER COUNTY

GENERAL CONDITIONS

Lancaster County is bounded on the west by Susquehanna River, on the south by the Mason and Dixon line, on the east by Chester County, and on the north by Berks, Lebanon, and Dauphin counties. The area is 941 square miles, and the population, according to the United States Census in 1930, is 196,882, of which 59,949 live in the county seat, Lancaster. The number of inhabitants per square mile is 209.2 as compared with 214.8 for the entire State. The same census gives the number of farms in the county as 9,716. The rural and urban populations are approximately equal. In addition to Lancaster, the following incorporated towns and boroughs are located in this county: Adamstown, Akron, Christiana, Denver, Elizabethtown, Ephrata, Lititz, Manheim, Marietta, Mount Joy, Mountville, New Holland, Quarryville, Strasburg, Terre Hill, and Washington Boro. The city of Lancaster uses surface water but most of the boroughs use ground water.

GEOLOGY OF LANCASTER COUNTY

For the convenience of the users of the Lancaster County section of this report, the following geologic column is inserted:

Geologic column for Lancaster County.[1]

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Triassic	Gettysburg shale. Red shale with soft red sandstone. The lower bed comprises the Elizabeth Furnace conglomerate member, 0 to 2500 feet of heavy beds of hard red to gray sandstone and conglomerate interbedded with softer red sandstone and shale.	4,500	A fairly good water-bearing horizon. Few wells are failures. The lower member should yield larger volumes of water. Where baked by intrusion the rock is impervious.
	New Oxford formation. Light gray to grayish yellow, arkosic, crumbly sandstone with interbedded thin red shale, some quartz pebble conglomerate near base.	4,500	A very good ground-water horizon. Some wells yield 200 or more gallons per minute.

[1] The data for this column were obtained from the following sources:
Knopf, E. B. and Jonas, A. I., Geology of the McCalls Ferry-Quarryville District, Pennsylvania: U. S. Geol. Survey Bull. 799, page 16 (Fig. 3), 1929.
Jonas, A. I. and Stose, G. W., Topographic and Geologic Atlas of Pennsylvania, Lancaster Quadrangle, Pennsylvania Top. and Geol. Survey, Atlas No. 168, 1930.
Jonas, A. I. and Stose, G. W., Topographic and Geologic Atlas of Pennsylvania, New Holland Quadrangle, Pennsylvania Top. and Geol. Survey, Atlas No. 178, 1929.
Bascom, F. and Stose, G. W., U. S. Geol. Survey Geol. Atlas, Coatesville-West Chester folio (No. 223), 1932.
Stose, G. W. and Jonas, A. I., Geology and mineral resources of the Middletown Quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, Pl. 3, 1933.

Age	Name and description	Thickness	Water-bearing properties
	Unconformity	Feet	
Upper and Middle Ordovician	Cocalico shale. (Martinsburg shale) Bluish black to dark gray fissile shale, purple and green shale with a thin quartzite near base.	2,000±	A poor water-bearing horizon. Most wells yield small supplies of hard water.
Lower (?) Ordovician	Conestoga limestone. Thin-bedded blue limestone and gray granular limestone at base. Unconformable on rocks down to the Vintage dolomite.	1,000±	
Lower Ordovician	Beekmantown limestone. Pure gray limestone, laminated magnesian limestone, and lenticular dolomite veined with calcite and quartz; contains black chert.	2,000±	
Upper Cambrian	Conococheague limestone Light-blue limestone banded with siliceous impurities, dolomite and fine-grain marble.	1,000±	Solid limestone is impervious but most limestones contain solution channels, many of which are water-bearing. The yield of wells depends upon their intersecting these water-bearing solution channels. The calcareous shales lack solution channels and are poorer aquifers than the limestones.
Upper and Middle Cambrian	Elbrook limestone. Thin-bedded to shaly, fine-grained, white to creamed-colored marble and limestone with sericitic partings.	1,000±	
Lower Cambrian	Ledger dolomite. Light gray pure granular dolomite with some rough-weathering chert.	1,000±	
	Kinzers formation. Dark shale below; blue banded limestone and spotted marble above.	200	
	Vintage dolomite. Dark blue knotty dolomite with impure white marble at base.	600±	
	Antietam quartzite. Gray quartzite with granular ferruginous quartzite at top.	300±	A fairly good water-bearing formation. Wells and springs yield small to medium supplies of excellent water.
	Harpers phyllite. Light gray phyllite and schist.	1,000±	Not a good water-bearing formation. Most wells yield small supplies.
	Chickies quartzite. Massive white quartzite and quartz schist with sericitic partings. Basal Hellam conglomerate member is a white quartz pebble conglomerate.	600±	Yields small supplies of excellent water.
	Unconformity		
Algonkian (Glenarm series)	Peach Bottom slate. Dark bluish-gray slate.	1,000±	Unimportant as aquifers on account of limited areal distribution. Few wells have been drilled in these formations.
	Cardiff conglomerate. Quartz pebbles in a schistose matrix of quartz, sericite and chorite.	?	
	Peters Creek schist. Chloritic and sericitic quartz schists interbedded with chlorite-sericite schists.	?	A fairly good water-bearing formation. Most wells in this schist yield small supplies of water.
	Wissahickon formation. Albite-chlorite schist north of the belt of Peters Creek schist and oligoclase-mica schist south of it.	?	A fairly good water-bearing formation. Few wells are failures and some yield more than 100 g.p.m.
Archean	Baltimore gneiss. Biotite-albite schist, quartzose and biotitic gneiss, in places graphitic.	?	Not a good water-bearing horizon. Few wells are dry but few wells yield more than 25 g.p.m.

Age	Name and description	Thickness	Water-bearing properties
	IGNEOUS ROCKS		
Triassic	Diabase. Dikes and sills of fine to medium-grained rock.	?	Poor water-bearing material.
Pre-Cambrian	Pegmatite (may be Cambrian or younger). Dikes or veins of coarsely crystalline feldspar, quartz, and mica and minor accessory minerals.		Not important as a source of ground water.
	Anorthosite. Chiefly coarse-grained feldspar with subordinate amount of accessory minerals.	?	A rather poor water horizon.
	Granite. Crystalline rock composed of orthoclase and quartz with subordinate amounts of other minerals. Includes quartz diorite, quartz monzonite and granodiorite.	?	A poor water-bearing horizon.
	Serpentine Includes pyroxenite and peridotite. Chiefly serpentine	?	A poor ground-water horizon.
	Gabbro. A coarse-grained rock composed of feldspar and ferromagnesian minerals.		A very poor water-bearing formation.

The geology of the county is complex and all three provinces, the old crystalline rocks, together with the Lower Cambrian quartzites and schists, the Cambrian and Ordovician limestones and shales, and the Triassic sediments, are found in the three belts stretching roughly east and west across the county—the old crystalline rocks in the south, the limestones in the central belt, and the Triassic rocks in the north. These belts are not separated by straight lines but by sinuous ones with numerous reentrants and offsets due to folding and faulting and subsequent erosion.

The pre-Cambrian formations and the Chickies quartzite, with the basal Hellam conglomerate member have been described and their water-bearing properties discussed early in this report. The Harpers phyllite is a gray phyllite in this county except in the Mine Ridge area where it is a schist. The phyllite is composed of albite, muscovite and quartz with some biotite; and the schist is an albite-mica schist. The water-bearing properties of these rocks are essentially the same as those given on page 40. The Vintage dolomite, Kinzers formation, Ledger dolomite, Elbrook limestone, Conococheague limestone, Conestoga limestone, and Cocalico shale are described and their water-bearing properties discussed on earlier pages. Several of these formations are named from places in this county. The New Oxford formation in this area resembles the formation in its type locality. The Gettysburg shale resembles also the shale at its type locality. A lenticular mass of heavy conglomerate, called the Elizabeth Furnace conglomerate member, (not shown on Plate I) with a maximum thickness of 2,500 feet is well developed in this county. It forms Furnace Ridge northeast of Mount Hope. The conglomerate may yield somewhat larger supplies to wells drilled in it than those drilled in the shale. However, it outcrops in an area where very few wells have been drilled.

The water-bearing properties of the igneous rocks which outcrop in this county have been discussed under that heading.

TOWNSHIP DESCRIPTIONS

East and West Cocalico townships. These townships occupy the northernmost part of the county and are underlain by Cambrian, Ordovician, and Triassic rocks. The Hardyston quartzite, of Cambrian age, which is so prominent in South Mountain, is the oldest rock outcropping in these townships. Few wells have been drilled in this quartzite in West Cocalico Township, but if the experiences in the vicinity of Grand View in the adjoining county are any criteria, there may be difficulty in obtaining supplies from this horizon. However, wells located either on the flat top of the mountain or advantageously in the ravines should yield 1 or 2 gallons a minute of water low in total dissolved solids and low in hardness. Small springs on the flanks of the mountain, if properly developed, would furnish sufficient water for numerous summer homes.

The Conococheague and Beekmantown limestones both outcrop in these townships and their water-bearing properties are quite similar. The well at the Walter Cigar Co., in Reamstown (No. 1), is in the Conococheague limestone just west of the fault separating the limestones from the Triassic beds.

The red shales and sandstones of the Newark group outcrop over a considerable area. They are the best water-bearing rocks in these townships and usually yield larger supplies than the adjacent Paleozoic rocks (Nos. 2 and 3). However, where the red rocks are almost entirely fine grained shales they yield very little water and wells are occasionally complete failures.

Brecknock Township. This township is underlain by the Newark group and intrusive diabase. The information concerning the Triassic rocks given in the preceding paragraph applies here, except that some of the sediments have been baked by the diabase intrusions; they are denser and less pervious, and consequently will yield less water than the unbaked rocks. Diabase will also yield smaller supplies but the quantity available is usually less than that obtainable from the sandstone and shales.

Caernarvon Township. Caernarvon Township is in the extreme eastern part of Lancaster County. The oldest rocks outcropping in this township belong to the Lower Cambrian Chickies quartzite, which forms the upper part of Welsh Mountain. The basal Hellam conglomerate member of the Chickies is also present. On account of the small but excellent springs furnishing adequate water for the needs of the small population of this upland area, few wells have been drilled. Little difficulty should be experienced in obtaining small supplies, but wells yielding large volumes of water will be exceptional due to the thoroughly cemented character of the quartzite and conglomerate (No. 4). The Harpers phyllite, which overlies the Chickies quartzite, outcrops along the north flank of Welsh Mountain and forms a series of low hills paralleling the mountain. It is also a source of small supplies. Few wells have been drilled in the phyllite but small springs are fairly numerous, and supply soft water with gravity flows. A

number of these springs have been improved by the farmers dwelling in the limestone valley and piped to their homes.

The phyllite is overlain by the Antietam quartz schist or by the Cambrian and Ordovician limestone series, which includes several formations that in this area are all similar in their water-bearing properties. The limestones are uncertain ground-water horizons. The northern part of this township is underlain by Triassic sediments, the water-bearing properties of which are discussed under East and West Cocalico townships.

Earl, East and West Earl townships. The oldest formation in these townships is gabbro which outcrops on the southern flank of Welsh Mountain in the extreme southern end of East Earl Township. Its areal extent is about 20 acres. Small supplies should be obtained though the percentage of dry wells may be high. The Hellam conglomerate member and the overlying quartzite of the Chickies, which rest on the gabbro and form the upper part of the mountain, should yield small supplies of water very low in total dissolved solids. The well of George Boley (No. 6) is drilled in a small mass of Chickies quartzite detached from the main mass by faulting. The Harpers phyllite, which overlies the Chickies quartzite, is a fairly good source of small domestic supplies but in all probability can not be depended upon to yield large municipal or industrial supplies.

The Antietam quartzite, overlying the Harpers phyllite, forms uplands where very few wells have been drilled and consequently little definite information is available. This quartz schist should yield small supplies for domestic use. The limestones which overlie the Antietam quartzite are of Cambrian and Ordovician age. They are, however, similar in their water-bearing characteristics. The well at the New Holland ice plant is 338 feet deep (No. 7). The temperature of the water from this well was 54° F., while that from an adjacent well, 274 feet deep, was 56° F. There was in September, 1925, no apparent reason for this difference of 2 degrees. The sandstone at the base of the Elbrook limestone may be a good water horizon, but, on the other hand, it may be tightly cemented and consequently yield very little water. In most places wells will yield a few gallons a minute, but in some, failures may occur even in the vicinity of successful wells (Nos. 7 to 12). Cisterns are numerous and furnish soft water for laundry and similar purposes.

The Cocalico shale is at the surface in West Earl Township where it overlies the Beekmantown limestone in a shallow syncline. This shale is a less favorable water horizon than the limestone on account of its dense, fine-grained character and its lack of solution channels. In most instances, however, small yields should be obtained by drilled wells but the water will be hard.

Triassic rocks outcrop in the vicinity of Terre Hill. The well of John Eschelman, at Terre Hill, is 65 feet deep and yields 15 gallons a minute (No. 14). Many wells in the red sandstones and shales are deeper and a few yield smaller volumes of water. However, except where the shale is dense and without interbedded sandstones it usually yields fairly large supplies. Frequently municipal and industrial supplies can be obtained although water softeners are usually necessary for industrial supplies on account of the hardness of the water.

Upper Leacock and Leacock townships. Both these townships are underlain chiefly by limestones, of which the Ledger dolomite has the largest area of outcrop. Wells in the Ledger dolomite suggest that this formation is an excellent water horizon (Nos. 16 and 17). Wells in the Elbrook limestones are doubtless indicative of the kind of wells to be expected (Nos. 18 to 28). Wells as shallow as the one at Monterey are usually not successful, while on the other hand, it is rarely necessary to go so deep as the well at the creamery. Yields in excess of 25 gallons a minute are not common.

Apparently the Conestoga limestone is not an excellent water horizon (Nos. 29 to 32). On the whole it appears to be very solid, and in many areas, free of solution channels and consequently yields but little water.

Salisbury and Sadsbury townships. These townships have a variety of rocks because parts of both Welsh Mountain and Mine Ridge are included in these civil divisions. The oldest rock outcropping in the area is the graphitic gneiss. The borough of Christiana is supplied by eight springs in the gneiss, the total yield of which is 90 gallons a minute. The water from these springs at the head of Pine Creek is distributed by gravity under a head of about 185 feet. (See analysis No. 34). The complex igneous intrusions of granite, gabbro, and related rocks should give small domestic supplies but large volumes of water can rarely be obtained from these rocks. The central part of Mine Ridge is also composed of igneous rocks. The well of Polk Russell at Smyrna (No. 35) is shallower than many wells in the vicinity, some of which are 200 feet deep, or more, but none of them are reported to yield large volumes of water. The igneous rocks are overlain by the Chickies quartzite with the Hellam conglomerate member at its base. These rocks yield small supplies of soft water low in total dissolved solids. The Harpers phyllite has been metamorphosed to schist in the vicinity of Mine Ridge, and except where thoroughly jointed is probably a poor water horizon. The Antietam quartzite outcrops in this township, but accurate well data are lacking on the water-bearing possibilities of this quartzitic horizon. They are probably similar to those of the Chickies quartzite. Of the limestone overlying the sandy Lower Cambrian formations the Ledger dolomite has the greatest area of exposure. A number of strong wells indicate the possibility of developing considerable supplies from the Vintage dolomite (Nos. 38 to 41). However, limestones and dolomites are erratic sources of supply. In most places the Ledger dolomite is massive with few joints or solution channels filled with water (Nos. 42 to 46).

South of the Mine Ridge is the narrow Chester Valley underlain by the Conestoga limestone. There are no data for wells in this limestone or this township, but judging from results in Chester County wells in this valley will show considerable range in depth and yield and some of them may be failures.

The upland region to the south of the valley is underlain by the albite-chlorite schist of the Wissahickon formation and by Peters Creek schist. These two rocks, which are lithologically so similar in many places as to be almost indistinguishable by the layman, are very similar in water-bearing properties. The data obtained in adjacent areas

indicate that these schists yield small supplies to wells drilled less than 250 feet, and that yields exceeding 25 gallons a minute are rare.

Paradise Township. The southern part of Paradise Township is on Mine Ridge where the pre-Cambrian crystalline rocks are at the surface. These rocks yield small quantities of water low in total dissolved solids. The borough of Strasburg has developed ten springs, which are all carefully bricked up and enclosed and yield 50 gallons a minute. The water flows to and is distributed by gravity in Strasburg. A sample of water was taken from one of the springs (See analysis No. 47). Although outcrops are scarce it is probable that the other springs issue from the gneiss and that the water is of the same quality. The borough has purchased another tract about 1 mile northeast containing five springs which have been developed but have not been used, although it is expected they will be in the near future. A composite sample of these five springs was taken (See analysis No. 48). These springs are probably in gneiss, but very close to the contact with the overlying Hellam conglomerate member of the Chickies quartzite. These five springs yield 35 gallons a minute. These analyses show that excellent water is obtainable from these rocks. The low temperature also makes them valuable for industrial use, but the quantity available is not large. In most cases small supplies are available in wells drilled but supplies in excess of 25 gallons a minute will be unusual. The Hellam conglomerate member and the overlying quartzite, which rest on the gneisses, are usually good water horizons and yield small supplies adequate for domestic use. The Harpers schist and Antietam quartzite overlie the Chickies quartzite. These rocks, where thoroughly broken up by jointing, should yield small supplies. They outcrop in a rough, rather thinly inhabited region where the main sources of water supply are dug wells and springs. Small springs are numerous on the north flank of the mountain and to supplement them a number of wells have been dug. Little information concerning these wells is available, but apparently they furnish, throughout the year, from 1 to 5 gallons a minute. These sandy formations are overlain by calcareous rocks in which ground-water conditions are quite different. The oldest of the calcareous formations are the Vintage dolomite, the Kinzers formation, and the Ledger dolomite, the water-bearing properties of which are discussed under the preceding townships. The yield of a well (No. 49) at Vintage is exceptional for the Vintage dolomite. The Conestoga limestone, of Ordovician age, is at the surface over a considerable area. Not far from well No. 51 a hole drilled for oil flows several gallons of water a minute. No log of this well is obtainable, and no information concerning the depth at which the water was struck. The anticlinal structure to the east may form the collecting ground for this artesian circulation and the well intersects the water-bearing Antietam quartzite, which may possibly yield the flow. This well begins in the Conestoga limestone, but it is highly improbable that the flow of water comes from this horizon.

Eden, Bart, and Colerain townships. The greater part of these townships is underlain by pre-Cambrian rocks. A notable and striking exception is the valley extending northeast from Quarryville which is underlain by the Conestoga limestone. The oldest formation outcropping in these townships is the chlorite-albite schist of the Wissahickon

formation. Most wells in these rocks will yield adequate domestic supplies (Nos. 52 to 54). In some places it may be necessary to drill 200 or 250 feet to obtain even 1 gallon a minute. The well at Murray Glen is a stronger well than the average (No. 52), but wells yielding as much as 25 gallons a minute may be encountered.

The borough of Quarryville obtains water from three springs in the albite-chlorite schist of the Wissahickon formation in the hills to the south. This water is distributed by gravity. It is typical of the waters from this schist (See analysis No. 55).

The albite-chlorite schist facies of the Wissahickon formation is overlain by the Peters Creek schist. These two schists are very similar, both in lithology and in water-bearing characteristics. Small domestic supplies can be obtained from this schist. In the southern part of Colerain Township numerous dug wells are in use which furnish adequate supplies in normal years, but in very dry years go dry. These wells obtain their supplies mainly at the junction of the fresh and disintegrated schist.

Mine Ridge cuts across the northern end of Eden and Bart townships. The core of this ridge is chiefly pre-Cambrian intrusive rocks of various types which are surrounded more or less symmetrically by a border of Cambrian and Ordovician sediments. The famous Gap nickel mine is in Bart Township. Although there was some water in this mine, the yield per square foot of opening was very small; at least, existing reports on this property do not mention that large volumes of water were encountered. This small yield indicates that these rocks are rather impervious; large supplies are rarely obtainable from them. The Chickies quartzite rests on the pre-Cambrian rocks. These quartz rocks are an excellent source of small supplies low both in total dissolved solids and hardness. The Chickies is overlain by the Harpers phyllite, which in this region has been metamorphosed to schist. The phyllite is overlain by the Conestoga limestone, which, due to its more rapid erosion, forms a valley. Wells in this limestone show that fairly large supplies can be obtained from the limestone (Nos. 59 to 61).

Clay, Elizabeth, and Ephrata townships. These townships are located in the northern part of Lancaster County. The northern part of Clay Township is in the Lebanon Valley. No data concerning wells in this area are available, but small yields should be obtainable.

The Beekmantown limestone underlies a broad valley where drilled wells should be fairly successful in obtaining small supplies.

The Conestoga limestone and the Cocalico shale both overlie the Beekmantown limestone. Judging from experience in adjacent areas these beds will yield small supplies of rather hard water.

The Newark group outcrops in a broad belt crossing both Elizabeth and Clay townships and in a somewhat narrower one cut off abruptly by a fault southwest of Ephrata. It consists of sandstones and shales in irregular succession which are predominantly red. The sandstone beds are usually better water horizons than the shales. The borough of Ephrata uses six springs along Ephrata Mountain as a source of public supply. In dry seasons supply from the springs is quite inadequate and must be augmented by water pumped from drilled wells, some of which are 8 inches in diameter and range from 91 to 139 feet in depth

(Nos. 64 to 66). A composite sample of the six springs was obtained (See analysis No. 63).

Warwick and Manheim townships. The oldest formation outcropping in these townships is the Conococheague limestone, which has been exposed by the erosion of the overlying Conestoga limestone. The well of Jacob Snyder, 1 mile northeast of Lititz, is 375 feet deep and yields 10 gallons a minute. The water is siphoned from the well at a much slower rate. This method of developing a gravity supply for houses is much used in some parts of the United States but is little developed in this part of Pennsylvania. The most famous springs in this region are the group known locally as the Lititz Big Spring. These springs and the well at the Animal Trap Co. (No. 68) suggest that the limestone contains numerous water-bearing solution channels. Several wells drilled in the Cocalico shale show that adequate supplies for household and small manufacturing plants are obtainable. (Nos. 69, 70). The shale is calcareous and the water is hard. A small area of Triassic rocks rests on the Paleozoic formations. The younger rocks are usually a more reliable source of ground water than the Paleozoic limestones and shales, if the experience gained in adjoining townships can be applied here.

Lititz obtains its municipal supply from a well in the limestone.

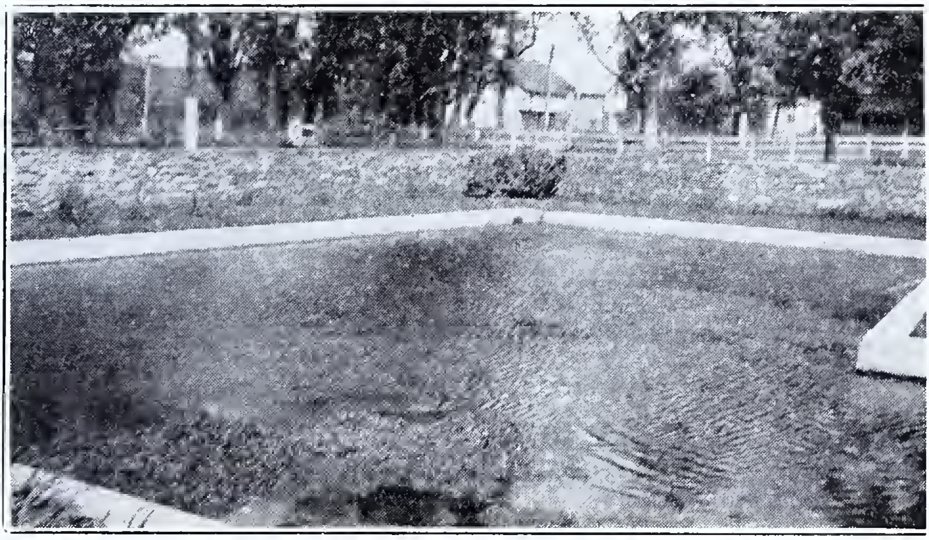
Lancaster, East and West Lampeter townships. These townships are underlain almost entirely by the Conestoga limestone. The Ledger dolomite is at the surface in part of East Lampeter township.

A large spring, known as Rocky Spring and located in Rocky Spring Park owned by H. B. Griffith, flows 50 gallons a minute. This spring is the chief natural attraction for this amusement park and is improved with a roof, concrete curbing, and steps, with proper screening and drainage to exclude foreign matter. An attractive feature is an electrically driven pump with a glass cylinder enabling the visitors to see how an ordinary pump operates. This spring furnishes all water needed in the park except for the swimming pool. The spring water is unusually clear. (See analysis No. 78). The spring shows some seasonal fluctuation but is apparently uninfluenced by the pumping of the wells less than 200 yards distant. Two wells about 40 feet apart supply the swimming pool with water at 49° F. (Nos. 79, 80). These wells yield 35 gallons each when pumped together or almost 70 gallons when pumped singly. The owner thinks that if more compressed air were available 70 gallons a minute could be obtained from each. The air line extends to the bottom of the well or 100 feet below the surface of the water when not pumping. The Big Spring on the property of Elizabeth A. Herr, 1 mile west of Lampeter, flows 50 gallons a minute. This very beautiful spring is in a large spring house and forms a pool about 50 feet square which is walled in with concrete. (See Plate 6 A.) While the spring fluctuates considerably it has never been known to go dry. (See analysis No. 81).

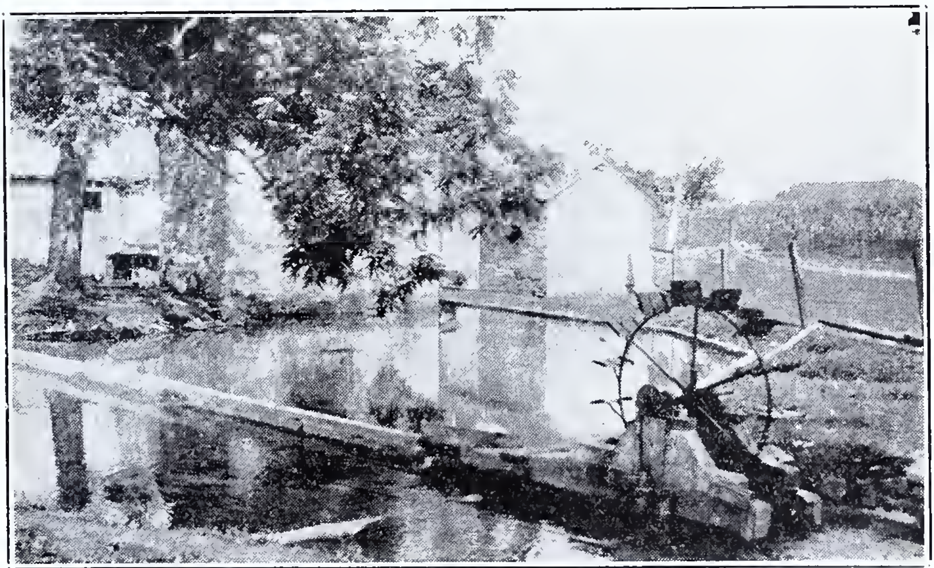
For wells in these townships see Nos. 71 to 90.

Strasburg and Providence townships. The Wissahickon formation is at the surface in Providence Township. For wells in this formation see Nos. 91, 92. The sandy Lower Cambrian formations outcrop in the hills south of Strasburg. Wells drilled in these formations usually yield small supplies of water very low in total dissolved solids and hardness. Large supplies are rarely obtainable.

PLATE 6.



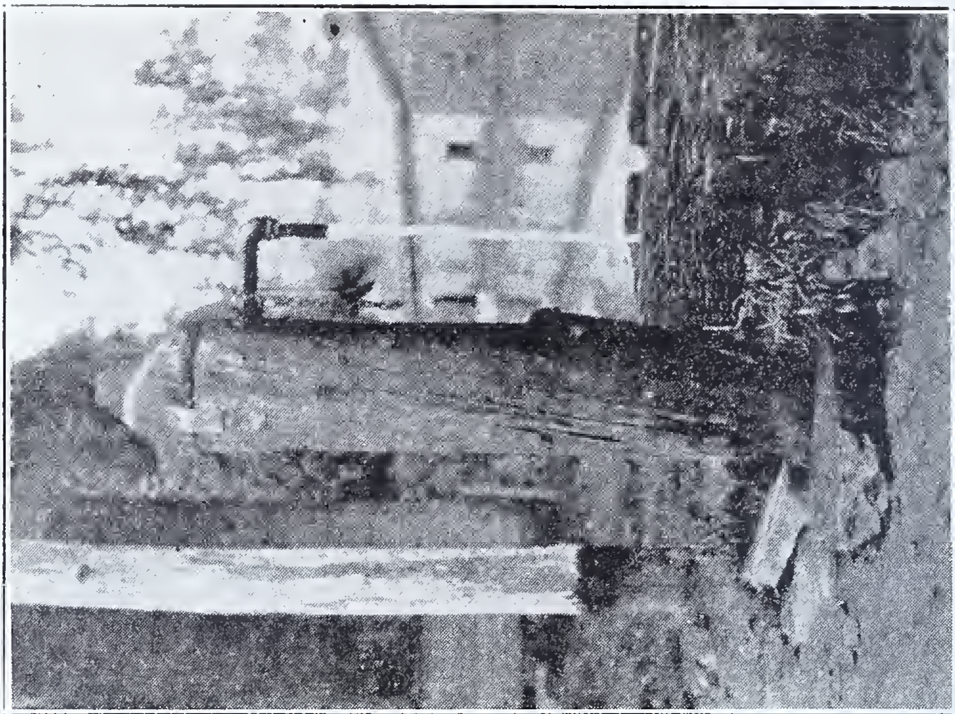
A. Big Spring, on Herr farm near Lampeter, Lancaster County.



B. Undershot wheel at Falling Spring, Aqua, Franklin County.

PLATE 7.

A. Falling Spring, Aqua, Franklin County.



B. Spring discharging through a post, near Mercersburg.

The Conestoga limestone, which outcrops in the vicinity of Strasburg, is not a uniformly good water horizon. On account of the excellent public water supply few wells are in use in Strasburg. There are, however, a number of abandoned wells, but information concerning them was not available. The public supply is so much softer that few people want to use well water.

Drumore and East Drumore townships. These townships are not thickly inhabited, and in the past dug wells and springs were adequate to supply all needs, but in recent years some wells have been drilled. With the exception of the northeast corner of East Drumore Township, the only rocks outcropping in the area are pre-Cambrian in age. The oldest of these is the albite-chlorite schist in the Wissahickon formation into which a number of wells have been drilled. (Nos. 93 to 96). The Wissahickon formation is overlain by the Peters Creek schist, which is almost indistinguishable from it, in this area. The water-bearing properties of the schists are about the same. These schists yield small domestic supplies but large supplies are uncommon. The Peters Creek schist is overlain by the Cardiff conglomerate and Peach Bottom slate. They are unimportant as aquifers.

Fulton and Little Britain townships. Fulton and Little Britain townships are the southernmost in Lancaster County. The Peters Creek schist is at the surface over a large area in these townships. The well of Ellsworth Carter, at Oakryn, is cased 60 feet through disintegrated schist and open for 9 feet through schist resembling soapstone. The first water was encountered at 20 feet. The level of the water in this well varies from 16 to 25 feet below the surface, depending on the season. Small supplies are obtainable from this schist. (Nos. 97 to 102). The Peters Creek schist is overlain by the Cardiff conglomerate and the Peach Bottom slate, in order named. The width of outcrop of these two formations is small, their areal extent limited, and their importance as aquifers is negligible. Along the Maryland-Pennsylvania boundary are several serpentine areas into which a number of wells have been drilled. (Nos. 103 to 108). Wells in these rocks show that small yields can be obtained but no large supplies are reported. A large intrusive mass of granodiorite is present in Fulton Township.

Rapho and Penn townships. The oldest formations outcropping in Rapho and Penn townships are the Cambrian and Ordovician limestones. The water-bearing properties of these limestones have been described on previous pages. The limestones are overlain by Cocalico (Martinsburg) shale from which moderate supplies can be obtained. (Nos. 112, 113).

The red sediments of the Newark group outcrop in the northern part of these townships. Judging by the data obtained in adjoining townships, little difficulty should be experienced in getting adequate supplies from the sandier beds although some of the shales may yield very little water. The yield of all of the wells is reported to decrease when they are pumped continuously. The tight character of the surrounding beds affords but little storage. These wells indicate that small domestic supplies are usually obtainable from the "red beds" but large municipal supplies can rarely be developed.

East and West Hempfield townships. The Chickies quartzite is the oldest formation outcropping in East and West Hempfield townships,

and the type locality is Chickies on Susquehanna River. This quartzite, including its basal Hellam conglomerate member, is exposed in an irregular group of hills. No data are available on wells drilled in these rocks, but it is probable that small supplies can be obtained by drilling wells to moderate depths. The Chickies quartzite is overlain by the Harpers phyllite and the Antietam quartzite. The borough of Mountville has experienced considerable difficulty in obtaining adequate supplies from these rocks. Three springs and eight drilled wells are used to supply the borough. The yield of these springs varies from 0 to 10 gallons a minute, according to the season, and this originally was adequate, but as the demand for water increased the wells were drilled. The springs are walled with masonry and covered with roofs. During the summer of 1925, two of the springs went dry and from the third one yielding about 5 gallons a minute a sample was taken. (See analysis No. 114). The wells range in depth from 138 to 360 feet, and in yield from 1 to 10 gallons a minute. (Nos. 115 to 122). Wells in the Conococheague limestone show the great difference in its water-bearing properties. (Nos. 124 to 136).

Manor Township. The oldest formation outcropping in Manor Township is the Wissahickon formation, which in general is more resistant to weathering than the limestone, and forms uplands.

The sandy Lower Cambrian formations, which overlie the Wissahickon formation, outcrop in this township and little data are available concerning wells drilled in them. The water-bearing properties of these formations, the Chickies quartzite, with its basal Hellam conglomerate member, the Harpers schist, and the Antietam quartz schist, are discussed under the preceding townships. The sandy Lower Cambrian formations are overlain by limestones of Cambrian and Ordovician age, the most important of which is the Conestoga limestone. Wells in this limestone show that it has about the same water-bearing properties in this township as in the adjacent ones. (Nos. 138 to 142).

Conestoga, Pequea, and Martic townships. The oldest formation at the surface in these townships is the Wissahickon formation. In general in this area successful wells adequate for domestic use can be obtained in it. The Wissahickon formation is overlain by the sandy Lower Cambrian formations, the Chickies quartzite, with the Hellam conglomerate member at the base, the Harpers phyllite, and the Antietam quartzite. The quartzite yields larger supplies lower in total dissolved solids than either the Harpers phyllite or the Antietam quartzite. The water-bearing properties of these formations are discussed under East and West Hempfield townships. These sandy beds are overlain by limestones, of which the Conestoga is the most important in this region.

Mount Joy, East and West Donegal, and Conoy townships. The most striking geologic feature in Mount Joy, West Donegal, and Conoy townships is the overlap of the Triassic sandstones and shales on the limestones of Cambrian and Ordovician age, but East Donegal township lies east of this contact. For limestone wells in these townships see Nos. 152 to 158. Where porous and well jointed rocks occur, large supplies can be obtained from the Triassic beds, but where they are dense and unbroken they yield little water. (Nos. 159 to 162).

DRILLED WELLS IN LANCASTER COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formations	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1	Walter Cigar Co.	Reamstown	50	6	Conococheague limestone		16	
2	Rheinholds Station	Rheinholds	80	6	Newark group		15	Water from red sandy shale
3	Canning Factory	Rheinholds Station	90	6	do		50	
4	J. Miller	2½ miles WNW. of Honey Brook	127	6	Chickies quartzite		3	See analysis
5	Ben Hoffert	Churchtown	65	6	Harpers phyllite		10	
6	George Boley	⅓ mile S. of Sorrell Horse	75	6	Chickies quartzite		5	
7	New Holland Ice Co.	New Holland	338	6	Elbrook limestone		21	Water enters at 125 feet; see analysis
8	Wood Worfel	Cedar Lane	84	6	do		3	
9	George Weaver	East Earl	70	6	do		10	
10	P. E. Shirk	Blue Ball	250	6	do	50	40	Small drawdown; public supply; see analysis
11	David Zimmerman	¼ mile S. of Vogansville	46	6	Beekmantown limestone		5	
12	John Sensenig	1 mile SE. of Hinkletown	80	6	Conestoga limestone		10+	Opening in limestone
13		Brownstown	60+	6	Martinsburg shale		10	Numerous wells
14	John Eschelman	Terre Hill	65	6	Newark group		15	Chickies quartzite
15	Henry King	Weavertown	75	6	Kinzers		25+	Opening in limestone
16	Chris. Peterscheim	Intercourse	60	6	Ledger dolomite		20	
17	Jason Eby	1 mile S. of Intercourse	65	6	do		15	Small drawdown
18	Jacob Stolzfuss	Monterey	35	6	Elbrook limestone		2	
19	Bareville Concrete Block Co.	Bareville	100	6	do		40	
20		do	100	6	do		10	
21	Conrad Commauf	Groffdale	106	6	do		10	
22	do	do	100	6	do		10	
23	do	do	81	6	do		10	
24	Elmer Groff	Bareville	60	6	do		5	Water over limestone cased out
25	Scott-Powell Creamery Co.	Mechanicsburg	300	6	do	50	60	Water enters at bottom
26	Harry Meilinger	do	63	6	do		2	
27	do	do	50	6	do		20	
28	do	do	69	6	do		2	
29	Kistler and Winger	1 mile W. of Paradise	130	6	Conestoga limestone		2	
30	Park Seed Co.	½ mile S. of Gordonville	385	6	do		2	Solid limestone
31	L. L. Hutchinson	Paradise	89	6	do		2	
32	Miles E. Cochrane	do	82	6	do		20	

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
33	----------	Roseboro (South Hermitage)	70	6	Baltimore gneiss	----------	8	Weathered rock
35	Polk Russell	Smyrna	46	6	Igneous rock	----------	2+	
36	Isaac McGinnis	Gap	65	6	Harpers schist (?)	----------	2	
37	John Eschelman	Kinzers	99	6	Kinzers formation	----------	7	
38	M. R. Evans	¾ mile E. of Kinzers	125	6	Vintage dolomite	----------	20	
39	Scott-Powell Creamery Co.	Gap	125	6	do	----------	60	
40	David Hartzler Ice Plant	do	49	6	do	----------	25+	Water in solution channel
41	John Kaufman	do	40	6	do	----------	10+	
42	Dr. Holstelter	Pequea, Salisbury Twp.	73	6	Ledger dolomite	----------	10	Small drawdown
43	Baptist Church	Cains	75	6	do	----------	2	
44	Arthur Burt	⅓ mile W. of Compass	90	6	do	----------	20	Small drawdown
45	Samuel Resser	2 miles N. of Cains	80	6	do	----------	8	
46	Ed. Mast	do	60	6	do	----------	4	
49	C. & W. Specialty Co., Inc.	Vintage	71	6	Vintage dolomite	----------	50+	
50	Harry Metzler	1½ miles E. of Strasburg	162	6	----------	----------	5	
51	Pennsylvania Railroad Tower	Leaman Place	80	6	----------	----------	40+	
52	----------	Murray Glen	45	6	Wissahickon	----------	5+	
53	Chris. Lamparter	½ mile SW. of Ninepoints	96	6	do	----------	2	
54	----------	Ninepoints	94	6	do	----------	3	
56	Georgetown Creamery	Georgetown	58	6	Granite (?)	----------	10+	
57	Amos Pickle	do	80	6	do	----------	10	
58	Robert McClure	Greentree	137	6	Harpers phyllite	----------	8	
59	Levi McAllister	Quarryville	100	6	Conestoga limestone	----------	25	
60	do	do	210	6	do	----------	1	
61	Ross Rohrer	Camargo	169	6	do	----------	20+	Cased to bottom
62	Jacob Shirk	1½ miles NW. of Brickerville	100	6	Newark group	----------	10	Red shale
64	Borough of Ephrata	Ephrata	201	6	do	----------	15	
65	do	do	205	6	do	----------	18	
66	do	do	407	6	do	----------	15	
67	Victor Kettner	Eden	105	6	Conestoga limestone	----------	20	
68	Animal Trap Co.	Lititz	50	6	do	1	300	Water from an opening
69	E. H. Kroft	Rothsville	72	6	Martinsburg shale	----------	20	
70	Knitting Mill	do	250	6	do	----------	10+	
71	Harry Hagenberger	Binkley	60	6	Ledger dolomite	----------	2	Several good wells in vicinity
72	Harry C. Smeltz	½ mile S. of Ronks	48	6	Conestoga limestone	16	20	See analysis
73	Charles Weaver	1 mile W. of Soudersburg	100	6	Ledger dolomite	----------	60	Two wells

74	E. W. Martin	1 mile E. of Lancaster	152	6	Conestoga limestone		15	See analysis
75	Jesse Mellinger	1½ miles E. of Lancaster	107	6	do		20	
76	Joseph P. Brennaman	1 mile E. of Greenland	105	6	do		20	See analysis
77	J. Weaver	Soudersburg	80	6	do		60	
79	H. B. Griffith	Rocky Spring Park	135	6			35	
80	do	do	135	6			35	
82	Old Rolling Mill	Lancaster	1,800		Conestoga limestone			Very little water near surface, dry from 500 feet to bottom; abandoned
83	Lancaster Sanitary Milk Co. N. Queen Street	do	500	6	do		2	Water near surface; two other wells also unsatisfactory
85	Falk Brothers	do	560	6	do		10	
86	Charles Kuntzler	do	300	6	do		30	
87	Adams Candy Co.	do	250	6	do		10	Water enters at 150 feet. Another similar well near by
88	Kepple Candy Co.	do	200	6	do	40	60	Water enters at 150 feet
89	John Boas	Bausman	126	6	do		2	
90	J. Martin	do	146	6	do		20	
91	Isaac Doulin	Truce	72	6	Wissahickon	27	5	Schist from 35 to 72 feet; see analysis
92	J. W. Doulin	do	79	6			8	Flows 10 months of year
93	Lancaster Security & Real Estate Company	Unicorn	80	6	Wissahickon		10	Hotel at Unicorn
94	Wealey Book	⅓ mile NW. of Unicorn	94	6	do		5+	
95	Ezra Eschelman	Mechanics Grove	90	6	do		12	59½ feet casing
96		do	80	6	do		5+	Three wells
97	Elmer Collins	½ mile SW. of Fairmount	100	6	Peters Creek schist		10	
98		Oak Shade	40	6	do		3	Water enters at 40 feet
99	Ellsworth Carter	Oakryn	63	6	do	16	8	See analysis and text
100	Little Brittain Presbyterian Church Parsonage	do	100	6	do		8	
101	Westbrook Creamery	Westbrook	46	6	do		30	Abandoned
102	Earl Platt	Wakefield	35	48 dug	do	30	5	Similar wells in vicinity; see analysis
103	Fred Carl	Grub Corners	69	6	Serpentine		10	
104	do	do	70	6	do		10	
105		do	100	6	do		3+	
106	Henry E. Brown	Lyles	40±	6	do		5	See analysis
107	V. W. Phipps	Wrightsdale	70	6	do		5	do
108	Jesse Wood	⅓ mile SW. of Lees Mill	60	6	do		3	
109	Harry Groff	1 mile E. of Quarryville	120	6	Conestoga limestone (?)		8	Black muck
110	Aaron Groff	1 mile E. of Quarryville	172	6	do		10	do
111	Myers Kreider	Manheim	85	6	do		30	Small ice plant
112	Old Line Creamery	Old Line	500	6	Martinsburg shale		20	
113	Frank Long	Sporting Hill	88	6	do		20	

No.	Owner	Location	Depth	Diameter	Water-bearing formations	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
115	Borough of Mountville No. 1	Mountville	209	8	Harpers schist	18	1½	20 feet of casing; see analysis
116	Well No. 2	do	360	8	do		10	Abandoned
117	Well No. 3	do	368	8	do		4	Tested 18 gallons a minute
118	Well No. 4	do	341	8	do		5	Tested 12 gallons a minute
119	Well No. 5	do	140	8	do			Abandoned
120	Well No. 6	do	278	8	do		8	Tested 8 gallons a minute
121	Well No. 7	do	277	8	do		2	
122	Well No. 8	do	138	8	do		8	
123	Daniel Brandt	Centerville	146	6	Antietam (?) quartzite		20	
124	A. Root	Mechanicsville	76	6	Conococheague limestone		20	
125	Benkley & Ober	½ mile N. of East Petersburg	177	6	do		3	Solid limestone
126	Rohrerstown High School	Rohrerstown	126	6	do		25	See analysis
127	Harvey Minnick	¼ mile NW. of Bamford	110	6	do		20	Slate
128	Taylor and Long	Landesville	300	6	do		2	
129		do	76	6	do		30+	100 feet from No. 128
130	A. H. Rudy	do	100	6	Conestoga limestone		30	
131	Miller Eschelman	Salunga	100	6	Conococheague limestone		5	
132	E. G. Myers	do	50	6	do	30	15?	Dropped 2 feet opening at bottom; see analysis
133		do	40–250	6	do		1–50	30 wells
134	Jackson Steel & Iron Co.	Columbia	300	6	do		30	
135	Columbia Coal & Ice Co.	do	265	6	do		15	Yield decreased and well has been abandoned
136	Harry Lawrence	1 mile S. of Rohrerstown	79	6	do		20	
137	Roy S. Kline	½ mile NW. of Creswell	85	6	Wissahickon		20	
138	Manor Township High School	Millersville	64	6	Conestoga limestone		20	See analysis
139	do	do	1,000	6	do		2	Solid limestone; 110 feet from No. 138
140	J. S. Pretzman	do	61	6	do		30	Opening near bottom
141	A. F. Stauffer	Washingtonboro	71	6	do		20	Open limestone; small drawdown
142	do	do	78	6	do		20	do do
143	J. Walter Miller	½ mile S. of Pequea	204	6	Wissahic on		5	Near river bluff
144	do	do	40		do		2	Dug well
145	Howard Campbell	do	147	6	do		8	75 feet higher than No. 143
146	E. Hill	Mt. Nebo	100	6	do		12	

147		do	100±	6	do		5+	Six wells
148	J. H. Steinman	2 miles NW. of Rawlinsville	110	6	do		12	
149	C. E. Wentz	Rawlinsville	55	6	do		12	See analysis
150	Benjamin Douts	½ mile E. of McCalls Ferry	104	6	do		½	On hill
151	do	do	63	6	do		6	Down hill from No. 150; see analysis
152		Marticville	100±	6	Conestoga limestone		5+	Several wells
153	Magnesia Works	Mt. Joy	150	6	do		60	
154	Baehman Chocolate Co.	Florin	515	6	do		30	
155	do	do	350	6	do		45	
156	Florin Water Co.	do	600	8	do		5	
157	do	do	237	8	do		65	
158	Rheems Waterworks	Rheems	200	6	do		15	
159	Masonic Home	Elizabethtown	306	10	Newark group		70	
160	Kline Chocolate Co.	do	380	6	do		60	
161	Hershey Chocolate Co.	do	350	8	do	25	100	
162		Bainbridge	80	6	do	25	1	

LEBANON COUNTY

Lebanon County is bounded on east, south, and west by Berks, Lancaster, and Dauphin counties and has an area of 360 square miles. Part of the county lies north of Blue Mountain. The population, according to the United States Census of 1930, is 67,103, and the number of inhabitants per square mile is 186.4 or 28.4 persons less than the average for the State. The number of farms in the county is 2,197. The rural and urban populations are approximately equal.

GEOLOGY OF LEBANON COUNTY

Detailed work on the geology of this county has not been published but the following column was compiled from a number of sources.

Geologic column for Lebanon County south of Blue Mountain[1]

SEDIMENTARY ROCKS

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Triassic	Gettysburg shale. Soft red shale and sandstone with some hard white conglomeratic sandstone near base. Baked and altered near intrusions.	6,000±	A fairly good water-bearing formation. Most wells yield small supplies. A less favorable aquifer where baked.
	Unconformity		
Upper and Middle Ordovician	Martinsburg shale. Soft red and yellow shale and sandstone, hard, gray, purplish-red shale, dark gray to bluish-black shale. Contains basalt and volcanic ash.	1,000±	A poor water-bearing formation. Most wells yield small supplies of hard water.
Middle Ordovician	Leesport "cement rock." Dark thin-bedded limestone and shale. Some calcareous quartzite in lower half.	40±	Unimportant as a source of ground water.
Lower Ordovician	Stones River limestone. Pure, thin-bedded, even-grained dove-colored limestone.	500±	The limestones are dense but wells which intersect water-bearing solution channels yield large supplies of water. Some wells are failures.
	Beekmantown limestone. Thick-bedded, pure limestone, laminated magnesia limestone, and "edgewise conglomerate."	1,000±	
Upper Cambrian	Conococheague limestone. Thin bedded, blue limestone, finely banded by thin siliceous laminae.	1,000±	
Lower Cambrian	Tomstown dolomite. Dolomite and shaly beds.	1,000±	
	Hardyston quartzite. Quartzite and schist.	40–300	Usually yields small supplies of good water.
	IGNEOUS ROCKS		
Triassic	Diabase. Dikes and sills of fine to medium-grained, dense rock.	?	A poor water-bearing formation.
Upper Ordovician	Basalt. Lava flows of dense, very fine-grained rock with associated diabase intrusion.	?	A poor water-bearing formation.
Pre-Cambrian	Granitic gneiss	?	Small yields.

[1] Stose, G. W. U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.
Stose, G. W. and Jonas, A. I., Ordovician shale and associated lavas in southeastern Pennsylvania: Bull. Geol. Soc. Am., vol. 38, pp. 505-536, 1927.
Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), 1929.
Stose, G. W. Unconformity at the base of the Silurian in southeastern Pennsylvania: Bull. Geol. Soc. Am., vol. 41, pp. 629-658, 1930.

GENERAL CONDITIONS

The cities and towns, like the rural population, derive their water supplies either from wells or springs. In places cisterns are used for the storage of rain water. The development of suburban life as well as the erection of new homes with modern conveniences in the rural districts has increased the interest of most people in ground-water supplies. Small pressure systems are the best method of supplying water to houses which cannot be connected, without too great expense, to a public supply.

The part of this county which lies north of Blue Mountain is not discussed in this report.

TOWNSHIP DESCRIPTIONS

Jackson, Mill Creek, and Heidelberg townships. The oldest rocks exposed in these townships are the pre-Cambrian crystalline rocks which come to the surface in South Mountain in the extreme eastern part of Mill Creek Township. The crystalline rocks yield small supplies, but only a few wells obtain more than 25 gallons a minute. The crystalline rocks are overlain by the Hardyston quartzite, which yields small supplies of very good water. Some water may be found at the contact of the crystalline rocks and the overlying quartzite.

Newmanstown obtains its supply from springs which issue from both the gneiss and quartzite. The Lebanon valley is underlain by Cambrian and Ordovician limestones. Wells in these limestones show that large quantities of water are available in this rock where cavernous. (Nos. 2 to 13).

The limestones are overlain by the Martinsburg shale. (No. 14).

In the southern part of the area the limestones are overlain by Triassic sediments which are chiefly red sandstones and shales. The red sandstones and shales usually yield fairly large supplies, and in many localities supplies adequate for industrial and municipal use are obtainable.

Swatara and Bethel townships. The Martinsburg shale and the Leesport "cement rock" are the only formations with which this report is concerned that crop out in Swatara and Bethel townships. The town of Fredericksburg obtains its supply from a combination dug and drilled well about 70 feet deep, the yield of which is relatively small. Although many wells drilled in the shale are successful at depths of about 50 feet, it is recommended that wells in the Martinsburg shale be drilled at least 100 feet deep because whether or not increased yield is obtained, the storage is invaluable and also decreases the possibility of the well going dry in very dry seasons when the water table drops. (Nos. 16 to 18). The Leesport "cement rock" is unimportant as a source of ground water.

North and South Lebanon, Cornwall, North and West Cornwall townships. The area included in these townships is the most thickly settled and contains the important city of Lebanon and its industries and the famous Cornwall magnetite mines.[1] The oldest rocks outcropping in the area are the "Valley limestones," of Cambrian and

[1] Spencer, A. C. Magnetite deposits of the Cornwall type in Pennsylvania: U. S. Geol. Survey Bull. 359, 1908.

Ordovician age. Wells in these limestones show that their water-bearing properties are similar to limestone elsewhere in this great valley. Wells which encounter water-bearing solution channels yield abundantly and those which do not are small producers or failures. (Nos. 19 to 30).

The limestones are overlain by the Martinsburg shale, which forms the low, ''slate'' hills north of the limestone valley. Wells drilled into the Martinsburg shale show that it will yield considerable volumes of water.

The southern part of the area included in these five townships is covered by red sandstones and shales of Triassic age, which cover the Cambrian and Ordovician rocks. The geology of the area is further complicated by the intrusion of diabase with which the magnetite deposits are genetically linked by Spencer. Except in the vicinity of Cornwall, where the mining company has impounded some streams for water supply, dug wells and springs furnish the needs of the rather sparse population in the rough uplands. The sedimentary rocks can usually be depended upon to yield fairly large supplies, but due to diabase intrusion the beds are baked and disturbed so that few predictions can be made concerning ground-water conditions. Diabase is at the surface over considerable areas. It usually yields small supplies of very good water low in dissolved mineral matter except iron which in some wells is sufficiently high that it is objectionable.

Union, East Hanover, and North Annville townships. The oldest formations outcropping in these townships are the Cambrian and Ordovician limestones, underlying the valley in which Annville is situated. The uppermost of these limestones is very high in calcium and a number of quarries have been opened between Annville and Palmyra which ship this pure limestone for cement mills, blast furnaces, and lime plants. All the quarries soon encounter solution channels filled with water so that the cost of pumping water is an expensive item. The quarries illustrate why wells that encounter solution channels yield heavily and wells which fail to penetrate solution channels are dry or yield meager supplies.

The limestones are overlain by the Martinsburg shale, which is areally by far the more important source of ground water. In most places the Martinsburg shale yields small supplies to wells. In places the water is hard and householders supplement their well supply with rain water stored in cisterns.

North and South Londonderry and South Annville townships. The oldest formations outcropping in these townships are the Cambrian and Ordovician limestones which outcrop in the valley. (Nos. 37, 39). One well was drilled through 55 feet of clay, 20 feet of iron-stone boulders, 10 feet of white limestone and ended in blue limestone. (No. 38).

DRILLED WELLS IN LEBANON COUNTY.

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gal. min.	
1	Borough of Richland		300	6	Hardyston quartzite		60	Sandstone
2	Mr. Yeiser	Newmanstown	90	6	Beekmantown limestone		40	White soft rock, rotten limestone (?)
3	School House	Millbach	150	6	do		20	
4	Allen Hauk	Richland	260	6	Leesport limestone		50	
5	Myerstown Gas Co.	Myerstown	200	6	do		50	
6	Harry Kohl	do	27	6	do	15	10	See analysis
7	do	do	28	6	do		25+	Cavernous rock
8	Hershey Chocolate Co.	do	80	6	do		120	Numerous openings
10	Lane Zook	$2\frac{2}{3}$ miles SW. of Myerstown	90	6	Conococheague limestone	60	15	
11	Mr. Hauser	Schaefferstown	90	6	do		25	
12	Hershey Chocolate Co.	do	190	6	do		35	
13	do	do	180	6	do		3	
14	Mr. Garloff	Kutztown	60	6	Martinsburg shale		15	
15		Schaefferstown	180	6	Conococheague limestone		15	
16		Jonestown	50	6	Martinsburg shale		15	
17		Near Bunker Hill	90	6	do		10	
18	David Yingst	Mt. Zion	90	6	do	20	15	Shale and sandy "slate," see analysis
19	Daniel Weaver	Lebanon	420	6	Leesport limestone		150	
20	Consumers Ice and Supply Co.	do	402	8	do		160	See analysis
21	George Ebright (Ice plant)	do	200	6	do		60	
22	Hershey Chocolate Co.	do	164	6	do	10	150	See analysis
23	Lebanon Sanitary Dairy Co.	do	400	6	do		22	Dry hole on same lot.
24	Edison Electric Co.	1 mile SE. of Lebanon	55	8	Beekmantown limestone		200	
25	Moses Yingst	3 miles E. of Lebanon	236	6	Leesport limestone		6	
26	Mr. Kreider	½ mile N. of Iona	300	6	Conococheague limestone		15	
27	School House	Iona	185	6	do	60	25+	See analysis
28	Samuel Yaegley	½ mile S. of Iona	300	6	do		5	
29	Monroe Smith	2 miles SE. of Lebanon	236	6	do		20	
30		$1\frac{1}{2}$ miles E. of Fontana	90	6	do	40	15	
31	George Boyer	Lebanon	150	6	Martinsburg shale	80	20	"Slate," see analysis
32	Iron City Brewing Co.	¾ mile N. of Lebanon	300	6	do		80	
33		$1\frac{1}{4}$ miles N. of Lebanon	75	6	do		20	
34	Daniel Weaver	1 mile NE. of Lebanon	350	12	do		250	Sandstone and "slate," reduced to 8 inches at 150 feet
35		$1\frac{1}{2}$ miles NE. of Lebanon	80	6	do		25+	
36	Annville Water Co.	Annville	300	10	do		50	Abandoned
37	Kaufman Farm	Near Mt. Pleasant	90	6	Conococheague limestone		10	Large opening in limestone
38	Mr. Oberholtzer	Campbelltown	120	6	Beekmantown limestone		20	
39	Mr. Horstig	Palmyra	120	6	do		15	
40		1 mile NW. of Heilmandale	80	6	Martinsburg shale		8	Abandoned

LEHIGH COUNTY

GENERAL CONDITIONS

Lehigh County is bounded by Northampton, Bucks, Montgomery, Berks, Schuylkill and Carbon counties, and has an area of 344 square miles. The population of the county, according to the United States Census of 1930, is 172,893, which is 502.6 persons to the square mile. The urban population comprises about two-thirds of the total population. The number of farms in the county is 2,313. This county is highly developed industrially, with consequent demands for large quantities of water for industrial and municipal use. In recent years many suburban and country homes have been erected beyond the limits of public supplies. In many places water has been obtained without difficulty, but in certain areas very few wells have been dug or drilled.

GEOLOGY OF LEHIGH COUNTY

The three belts of rocks mentioned earlier—crystallines, Valley limestone and shale, and Triassic beds—are found in this county.

Geologic column in Lehigh County[1]

SEDIMENTARY ROCKS

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Triassic	Brunswick shale. Red sandstones and shales with some "fanglomerate" at top.	5,000±	Usually fairly large supplies at depths of 25 to 500 feet.
	Unconformity		
Upper and Middle Ordovician	Martinsburg shale. Thin black fissile shale with some limestone at base and sandy shale and shaly sandstones in the middle. The shales altered to slate in eastern part of county.	3,000	Yields small to moderate supplies.
Middle Ordovician	Leesport "cement rock." Dark argillaceous limestone with white veins of quartz and calcite.	400±	A rather poor water-bearing horizon.
	Jacksonburg limestone. Pure limestone.	150±	Pure limestone which has solution channels and is therefore a good source of water.
Lower Ordovician	Beekmantown limestone. High-magnesium, usually heavy-bedded limestone.	1,000±	Uncertain water horizon. Some wells yield large volumes.
Upper Cambrian	Conococheague limestone. Mostly dolomitic. Many heavy ledges, some sandy and crinkly.	1,500±	Uncertain water horizon. In places large springs issue from thin-bedded limestone.
Lower Cambrian	Tomstown dolomite. Heavy-bedded dolomite with shaly beds. Outcrops along mountains frequently covered by quartzite float.	1,000±	Uncertain water horizon. Small supplies usually obtainable.
	Hardyston quartzite. A quartzite in beds of variable thickness. In some areas upper shaly layers altered to white micaceous rock.	20 to 300	Usually yields small but excellent supplies.
Archean	Baltimore gneiss (?). A complex group of gneisses of sedimentary origin. Some associated gneiss of igneous origin present.	?	Small supplies.

IGNEOUS ROCKS

Age	Name and description	Thickness	Water-bearing properties
Triassic	Diabase. Dark gray fine-grained igneous rock called "trap" intruded chiefly as dikes and sills in older rocks.	?	Small supplies.
Pre-Cambrian	Granite, gabbro, etc., injected in the older gneiss.	?	Small supplies.

[1] This column has been compiled from the following publications:
Miller, B. L., Topographic and Geologic Atlas of Pennsylvania, No. 206, Allentown Quadrangle, 1925.
——— Limestones of Pennsylvania, Penna.; Top. and Geol. Survey, Bull. M7, 1925.
Behre, C. H., Jr., Slate in Northampton County, Pennsylvania: Penna. Top. and Geol. Survey, Bull. M9, 1927.
Stose, G. W., Unconformity at the base of the Silurian in southeastern Pennsylvania: Bull. Geol. Soc. America, vol. 41, pp. 629–658, 1930.

TOWNSHIP DESCRIPTIONS

Lynn, Heidelberg, and Washington townships. Few wells have been drilled in the Martinsburg shale, which everywhere underlies Lynn, Heidelberg, and Washington townships. Some beds in this shale are altered to slate in the vicinity of Slatedale and Slatington. In the past, springs and dug wells, many of them half a century old, were the main source of water for the inhabitants. The water from the shale is in many wells hard and many dwellings have cisterns for storing rain water. Slatington obtains its supply from two groups of springs about 1¾ miles northwest of the borough at the foot of Blue Mountain. The water is collected in two reservoirs and is piped to Slatington with sufficient pressure for distribution by gravity. Wells drilled in the shale and slate generally yield a few gallons a minute.

Weisenberg, Low Hill, and North Whitehall townships. The Martinsburg shale is at the surface over most of these townships. The water-bearing properties of these shales are discussed under the preceding townships. The Martinsburg shale has been removed by erosion in the southern part of North Whitehall Township, and limestone is exposed. The water-bearing properties of the limestone are discussed under the following townships.

Whitehall and Hanover townships. The oldest rock in Whitehall and Hanover townships is the gneiss exposed in the hill above Lehigh River in the southern part of Hanover Township. A number of wells have been drilled in this rock (Nos. 1a, 1b, 1c, 2a, and 2b). They indicate that in some places large supplies can be obtained, but that in many places only small supplies can be had from these dense crystalline rocks.

The gneiss is overlain by the Hardyston quartzite, which forms a band of variable width on the north and west sides. Wells Nos. 3 and 4 indicate that large supplies have been obtained from the quartzite, but such large supplies can not everywhere be obtained from this rock. The water is usually very soft.

The Hardyston quartzite is overlain by limestones which range in composition from dolomite, through pure limestone, to "cement rock." Many wells have been drilled into these limestones and some of them yield large supplies (See Nos. 5 to 24). Springs are numerous and some of them are large. Crystal Spring, in Allentown, which is probably

the largest in these two townships, yields nearly 3,000 gallons a minute and is used as part of the city supply. Large springs issue from the banks along Lehigh River near Hokendauqua. The presence of the large springs indicates that large solution channels filled with water exist in this area. The large yields from some wells are obtained from these channels. In most wells there is some artesian pressure, but in only a few wells located in low places is it sufficient to bring the water so close to the surface that suction pumps can be used. Although many wells in this area yield large supplies, failures to obtain water will occur even in the vicinity of strong wells.

The limestones are overlain by the Martinsburg shale, but in the area where the Martinsburg shale is at the surface it is unimportant as a source of water.

South Whitehall and Salisbury townships. The oldest formations outcropping in South Whitehall and Salisbury townships are the gneiss and schist exposed in South Mountain. The wells in South Allentown show that fairly large supplies can in some places be obtained from these rocks, but that in other places only small quantities of water are available. (See Nos. 26a, 26b, 27, and 28). Small yields are much more common than large ones. The spring of Charles Erney issues from the gneiss and yields about 25 gallons a minute. This water contains only 88 parts per million of total dissolved solids and 11 parts per million of hardness. For analysis see No. 31.

The gneiss is overlain by the Hardyston quartzite, which forms a band around the edge of South Mountain except where it is cut off by faults. The two drilled wells of the borough of South Allentown (Nos. 29a, 29b) and the drilled well of the Waldheim Camp Association (No. 30) show that some wells obtain large supplies. However, other wells have been reported that have not obtained such large yields.

The Hardyston quartzite is overlain by limestone. Many wells have been drilled into the limestone, and their yields are quite variable. (See Nos. 32 to 38). Dry holes occur but in most instances small supplies are obtained. On many farms cisterns are used to store rain water for washing because the limestone waters are hard. The largest supplies are obtained from six 8-inch drilled wells of the Pennsylvania-Trojan Powder Co., which range from 300 to 500 feet in depth, and have a static water level of 160 feet below the surface and yield approximately 100 gallons a minute each, with a drawdown of about 55 feet.

The limestones are overlain by the Martinsburg shale. This shale is at the surface over only a small area and only a few wells have been drilled into it. (See Nos. 39, 40). These wells show that small supplies can be obtained from the shale. In the drilled well of John Eckert (No. 39) water rose within 10 feet of the surface and when the well was intersected by a tunnel it flowed 3 gallons a minute. On a pumping test at 6 gallons a minute it is said to have had a drawdown of 190 feet.

Upper and Lower Macungie townships. The oldest rocks outcropping in Upper and Lower Macungie townships are the gneiss and schist. These rocks, together with the overlying Hardyston quartzite, are of little importance as sources of water on account of their re-

stricted area of outcrop. However, a number of small springs that rise in this area furnish water for Macungie.

The Hardyston quartzite is overlain by limestones which furnish moderate quantities of water to a number of wells. (See Nos. 41 to 43). A large spring on the Mosser property about half a mile west of Trexlertown yields 250 gallons a minute. (See analysis No. 44). The city of Allentown obtains part of its water supply from Schantz's Spring, which yields more than 5,000 gallons a minute.

The limestone is overlain by the Martinsburg shale, which supplies the drilled well at the Lehigh Community Park (No. 45). In most places small supplies can be obtained by drilling wells into the shale.

Upper and Lower Milford and Upper Saucon townships. The oldest rock outcropping in these townships is the gneiss in the South Mountain, which supplies considerable water to a number of wells. (See Nos. 46 to 50). The Mountain Water Co. has two drilled wells (Nos. 50a, 50b) a quarter of a mile south of Emaus which yield 35 and 25 gallons a minute, respectively. These wells are drilled through the quartzite into the gneiss and probably get a considerable amount of water at the quartzite-gneiss contact. These are good strong wells and indicate that supplies up to 50 gallons a minute are obtainable from the gneiss. Many wells in the gneiss, however, yield much smaller supplies, as is shown by a well 700 feet deep, drilled for the borough of Emaus which yielded less than 5 gallons a minute and was abandoned.

The gneiss is overlain by the Hardyston quartzite. Few wells have been drilled in this formation in this area but south of Emaus the Mountain Water Co. uses springs which issue from the quartzite. A tunnel driven into the mountain obtains a considerable volume of water at the contact of the quartzite and the gneiss.

The Hardyston quartzite is overlain by limestone which supplies two strong wells that belong to the borough of Emaus but are situated in Salisbury Township (Nos. 51a, 51b). Well 51b furnishes most of the supply for the borough. (See also Nos. 52, 53, 54a, 54b). In the operation of the zinc mines at Friedensville considerable difficulty was experienced in handling the water that entered the mines through solution channels in the limestone. The drilled well of A. S. Weibel (No. 55) in Lanark is 262 feet deep and yields 75 gallons a minute. This well is in the Tomstown limestone. These successful wells and the water in the workings of the abandoned zinc mines indicate that large volumes of water are available in the limestones.

The limestones are overlain by Triassic rocks, chiefly the quartzose conglomerate which is near the top of the Newark series. (See Nos. 56 to 58). The borough of Coopersburg is supplied by well No. 58 and by two other drilled wells and a group of springs.

DRILLED WELLS IN LEHIGH COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1a	Allentown State Hospital	1 mile S. of Rittersville	770	8	Granite gneiss	90	35	
1b	do	do	700	8	do	90	50	
1c	do	do	270	8	do	90	80	
2a	Allentown Foundry-Hardware Co.	¾ mile S. of Rittersville	220	6	do		4	
2b	do	do	120	6	do		7	
3	Allentown State Hospital	1 mile S. of Rittersville	160	8	Hardyston quartzite		80–100	
4	Lehigh Valley Traction Co.	¼ mile W. of Rittersville	230	6	do	32	50	Water enters at 180 and 215 feet.
5	National Silk Dyeing Co.	East Allentown	125	6	Tomstown limestone	25	40	Water enters at 70 feet.
6	Allen Tire and Rubber Co.	do	202	8	do	35	100	Drawdown 10 feet.
7	Lehigh & New England Coal Storage Co.	West Bethlehem	365	8	Conococheague limestone	7	100+	Suction pump.
8	Allentown Merchants Ice Co.	Allentown	324	6	do	12	150	See analysis.
9	Neuweiler Brewing Co.	do	407	10	do	12	200	Low ground; suction pump.
10	Boat & Swimming Club Adam's Isle	Allentown	110	6	Tomstown limestone	15	40	Top 40 feet in alluvium.
11	L. F. Grammes & Sons	Union St., Allentown	404	8	Conococheague limestone	20	70	Water enters at 380 feet.
12	Arbogast-Bastian Co.	Allentown	708	8	do		350	Water enters at 300 and 425 feet; quartzite at 600 feet; ends in gneiss.
13	Jordan Silk Dyeing Co.	North Allentown	100	8	do	25	100	Water enters at 50 and 90 feet.
14	M. P. Schantz	½ mile NW. of Allentown	270	6	do	110	15	Small drawdown.
15	Lehigh Silk Dyeing Co.	1 mile N. of Allentown	229	8	do	15	100	Water enters at 90 and 140 ft. Suction pump.
16	Oscar Henninger	Mickley Pike, 1 mile W. of Fullerton	125	6	do	30	12	Water enters at 110 feet.
17	McBride Brothers	Fullerton	300	6	do	135	50	Clay and gravel; ends in limestone.
18	John Mylander	½ mile W. of West Catasauqua	130	6	do	90	15	
19		South Catasauqua	237		do			Dry hole.
20	C. L. Lehnert Brewing Co.	Catasauqua	204	6	do	80	80	Water enters at 200 feet.
21	A. F. Kostenbader	do	205	8	do		150	Water enters at 30 to 75 feet.
22	Crystal Ice Co.	do	107	8	do	18	150	Water enters at 75 feet.
23a	Borough of Catasauqua	¼ mile E. of Catasauqua	220	8	do	18		Water enters at 220 feet; combined yield of 23a and 23b is 1,000 g.p.m.

23b	do	do	240	8	do	18		Water enters at 240 feet.
24	Sylvanus Peters	Schoenersville	157	6	Beekmantown limestone	115	15	
26a	E. F. Miller	South Allentown	268	8	Granite gneiss		30	Water enters chiefly at 80; flowed 10 g.p.m. when completed.
26b	do	do	187	8	do		70	do
27	Security Realty Co.	1¼ miles SE. of Mountainville	165	6	do		7	
28	Children's Home Association	½ mile SW. of South Bethlehem	245	6	do		1	Practically dry, sandstone and schist.
29a	Borough of South Allentown	South Allentown	225		Hardyston quartzite		225	Water enters at 160 feet.
29b	do	do	176		do		150	Water enters at 170 feet.
30	Waldheim Camp Association	¾ mile S. of Mountainville	325	8	do	60	50	Water enters at 300 feet.
32	Salisbury School	Mountainville	153	6	Tomstown limestone	30	15	Water enters at 130 feet.
33	Stuyvesant Silk Mill	Aineyville	200	6	Conococheague limestone	60	40	Water enters at 180 feet.
34	Keystone Textile Co.	do	255	6	do	45	40	Water enters at 190 and 245 feet.
35	Allen Hagenbuch	2 miles SW. of South Allentown	140	6	do		15	
36	Cedar Crest College	1½ miles E. of Allentown	400	6	do	90	50	Drawdown 110 feet.
37	Hamilton Park Realty Co.	¾ mile E. of Allentown	407	10	do		15	Abandoned.
38a-38f	Pennsylvania-Trojan Powder Co.	½ mile NE. of Jordans Bridge	300 500	8	do	160	100+	Drawdown 55 ft; 6 wells.
39	John Eckert	Eckert	450	6	Martinsburg shale	10	3	
40	Fred Sterner	½ mile N. of Eckert	366	6	do	185	10	Large drawdown.
41	Charles Kuhns	½ mile S. of East Texas	60	6	Conococheague limestone	8	15	
42	Robert Mertz Hotel	Wescosville	133	6	do		10	
43	George Mosser	1¼ miles W. of Trexlertown	140	6	Beekmantown limestone	90	15	
45	Lehigh Community Park	1¼ miles NE. of Fogelsville	145	6	Martinsburg shale		25	
46	Charles Yaeger	1½ miles S. of Mountainville	145	6	Granite gneiss	30	20	Drawdown 70 feet.
47	Laura Kuntz	Summit Lawn, 1¼ miles S. of Mountainville	186	6	do	25	50	Water enters at 175 feet.
48	R. P. Stevens	1¼ miles S. of Mountainville	93	6	Granite gneiss	45	50	Water enters at 90 feet.
49	Borough of Emaus	¼ mile E. of Emaus	700	6	do			Abandoned.
50a	Mountain Water Co.	¼ mile S. of Emaus	200	8	do		35	Through quartzite into gneiss.
50b	do	do	120	8	do		25	do
51a	Borough of Emaus	N. of Emaus	260	8	Tomstown limestone		125	See analysis.
51b	do	do	325	10	do		200	See analysis.
52	H. Kostenbader Brewing Co.	Emaus	270		do			In sinkhole. Little water.
53	Emaus Silk Co.	do	125	6	do	70	50	Water enters at 110 feet.

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
54a	J. B. Yaekel	½ mile N. of Center Valley	95	6	Tomstown limestone	35	50	Drawdown 20 feet.
54b	do	do	200	6	do		5	On hill.
55	A. S. Weibel	Lanark	262	6	do	80	75	Drawdown 70 feet; see analysis.
56	Dieenscheid & Weinberger Orchard	1 mile W. of Steinsburg	62	6	Brunswick shale		2	Flows.
57	Gabriel Hosiery Co.	Coopersburg	160	8	do		100	Flows; red shale to 100 feet; then red sandstone. Water enters at 75 and 135 feet.
58	Borough of Coopersburg	do	300	8	do	35	100	Water enters at 140 and 210 feet.

MONTGOMERY COUNTY

GENERAL CONDITIONS

Montgomery County is surrounded by Berks, Bucks, Philadelphia, Delaware, and Chester counties, and has an area of 484 square miles. The population according to the United States Census of 1930 is 265,-804, or 549.2 per square mile. Its density of population is much greater than the average for the State. In spite of its proximity to Philadelphia and the presence of factories in many of the towns, the county still has a large rural population, and 3,356 farms. With the exception of Norristown, the county seat, which has a population of 35,853, and several other boroughs, the inhabitants are dependent almost exclusively upon subsurface sources for their water supply.

The county is a prosperous farming region with numerous small towns and villages with factories and mills which produce a variety of products that find a wide market and add to the material prosperity of the inhabitants. The land is rolling and the numerous prosperous farms make the region most attractive. The diabase ridges, usually wooded, are prominent features in a county where all tillable land is cleared.

The Triassic rocks are at the surface over the greater part of the area. In the southern and eastern parts, however, the older Paleozoic and crystalline pre-Cambrian rocks are exposed. The following geologic section is included for the convenience of the user of this section of the report.

Geologic column of Montgomery County[1]

Age	Name and description	Thickness	Water-bearing properties
Quaternary (Pleistocene)	Sunderland (?) formation. Sand, clay and gravel.	0-10	Thin deposit. Little or no water.
Tertiary(?) (Pliocene ?)	Bryn Mawr gravel. Sands and gravel.	0-20	Thin deposit. Little or no water.
Lower Cretaceous	Patapsco formation. Highly colored clay.	0-100	Small areal extent. Poor water horizon.
Upper Triassic	Brunswick shale. Chiefly soft red shale. "Fanglomerate" at the top.	13,000±	Small supplies. 1-10 gallons a minute obtainable at depths of 30 to 150 feet.
	Lockatong formation. Dark, hard shale, fine-grained sandstone, some red shale.	3,000±	Small supplies of 1-5 gallons a minute at depths of less than 250 feet. Failures to obtain water may occur.
	Stockton formation. Gray, yellow, and brown sandstone, arkose, conglomerate and some red shale.	4,000±	Excellent aquifer. Supplies up to 200 gallons a minute. Average yield less than 50 gallons a minute.
Ordovician and Cambrian	Blue-gray, dove-colored limestone and dolomite with some calcareous shale.	?	Yield of wells depends on encountering waterbearing solution channels. Wells 20-250 feet deep.

[1] This column was compiled from the following sources:

Bascom, F., and others, U. S. Geol. Survey Geol. Atlas, Philadelphia folio (No. 162), 1909.

Bascom and others, Geology and mineral resources of the Quakertown-Doylestown district, Pa.-N. J.: U. S. Geol. Survey Bull. 828, 1931.

Age	Name and description	Thickness	Water-bearing properties
Lower Cambrian	Ledger dolomite. Light gray, granular dolomite.	1,000±	Solid limestones are poor aquifers. Due to presence of water-bearing solution channels some wells yield large supplies. The shales are poor aquifers.
	Kinzers formation. Dark shale (in part altered to schist) below, and hard blue limestone and white spotted marble above.	200±	
	Vintage dolomite. Dark blue knotty dolomite with impure marble at base.	600±	
	Antietam quartzite. Gray laminated quartzite.	300±	Yields small supplies.
	Harpers phyllite. Light gray phyllite and dark banded slate. Where altered to schist it is a quartz-mica schist.	1,000±	Yields small supplies.
	Chickies quartzite. Sandstone, quartzite, conglomerate, quartz schist.	1,000±	Small supplies of excellent water. Depth of wells 50-250 feet.
Pre-Cambrian	Wissahickon formation. Oligoclase-mica schist.	?	Fairly good water horizon.
	Baltimore gneiss. Quartz, feldspar, hornblende, mica, banded rock; granitic in places.	?	Yields small supplies to drilled wells.
	IGNEOUS ROCKS		Small yields.
Triassic	Diabase. Fine to medium-grained crystalline rock composed of feldspar and augite.	?	
Pre-	Serpentine. Soft fine-grained green rock.	?	Poor water horizon. Water frequently highly mineralized.
Cambrian	Gabbro. Medium to coarse-grained crystalline, consisting chiefly of feldspar and pyroxene.	?	Poor water horizon.

Baltimore gneiss is exposed in a strip of variable width which cuts across the southern part of the county. The gneiss is usually conspicuously banded although it is granitic in places.

Ordovician and Cambrian limestones outcrop in the southern part of the county. They consist of a series of limestones and dolomites with some calcareous shales. The limestones usually weather to a deep clay soil and natural outcrops are not numerous, but exposures in rapidly eroding stream valleys, railroad and highway cuts, and quarries permit the examination of these beds. The limestones vary greatly in composition from place to place and every gradation from pure limestone to dolomite and from pure limestone to shale occurs. Some beds are conglomeratic and sandy. In part of the county these limestones have been divided into several formations, but in other areas they are still unseparated.

The Triassic rocks were laid down upon the older rocks of the region, but in most places they doubtless rest upon the Ordovician limestone. The depth to the contact of the limestone and the overlying sediments is in most places unknown and estimates are untrustworthy. The Triassic rocks are a series of alternating sandstone and shale with subordinate amounts of other types of sediments. They are divided from bottom to top into three formations—the Stockton formation, the Lock-

atong formation, and the Brunswick shale. The thicknesses of these formations are indefinite on account of the difficulty of measuring them.

The formations named in the geologic column are described in the introductory part of this report.

TOWNSHIP DESCRIPTIONS

Upper Hanover, Douglass, New Hanover, Upper, Lower, and West Pottsgrove, Frederick, and Limerick townships. The only formations outcropping in these townships are the Brunswick shale and the diabase, both of Upper Triassic age. The well of the Schwenkville Water Co. (No. 9) is reported by the driller to have penetrated 250 feet of blue shale and blue stone followed by 95 feet of sticky red shale in which the water is obtained. This and other wells show that water can usually be obtained from the Brunswick shale. (Nos. 1 to 23).

Diabase dikes outcrop in this region, but few records of wells ending in them were obtained. (See No. 24).

The boroughs of Pottstown, Royersford, and East Greenville are dependent upon surface streams for their water supplies. Surface waters are in most cases softer than water from the Brunswick shale.

Marlborough, Salford, Upper and Lower Salford, Skippac, Perkiomen, Upper and Lower Providence townships. The three Triassic formations are exposed in the area included within these townships. The Stockton formation outcrops in a belt which crosses Upper and Lower Providence townships. Wells in this formation indicate that little difficulty should be experienced in developing domestic supplies by drilling wells about 100 feet deep. (Nos. 25 to 27). Larger supplies should be obtained at depths ranging from 100 to 500 feet. In most places the Stockton formation can be depended upon to yield industrial and municipal supplies.

The Stockton formation is overlain by the Lockatong formation which outcrops in relatively narrow strips in Upper and Lower Providence townships. The strips which narrow rapidly westward form low hills or ridges several miles in width that rise a few feet above the lower rolling country underlain by the Brunswick shale and the Stockton formation. The Lockatong formation is not a good water horizon and although small domestic supplies can be developed by drilling wells, some failures to obtain water occur. (Nos. 28 to 32).

The Lockatong formation is overlain by the Brunswick shale. This shale is the surface formation over the greater part of this area and can be depended upon to yield small supplies to drilled wells. (See Nos. 33 to 43). Large supplies are more uncertain but the experience in the adjacent areas suggests the possibility of developing supplies of 100 gallons a minute, or more, at depths of 250 to 500 feet. Diabase dikes are numerous in the northern part of the area.

Franconia, Hatfield, Towamencin, Worcester, East and West Norriton, Plymouth, and Upper Merion townships. The oldest formation cropping out in these townships is the Baltimore gneiss which comes to the surface in the extreme southeastern part of Upper Merion Township. The area over which the gneiss is the surface formation is so small that it is unimportant as a source of water. The Baltimore gneiss is overlain by the Wissahickon formation, which in this area is

an albite-chlorite schist. The well of George R. Park (No. 44) is in this formation. The Wissahickon formation is overlain by the Chickies quartzite, which is limited in its areal extent, except in the Valley Forge area, where several successful wells have been drilled into it.

The Chickies quartzite is overlain by limestones of Cambrian and Ordovician age. The well of T. J. Kirkpatrick (No. 47) is drilled through a thickness of more than 150 feet of Harpers phyllite into the limestone from which the water is obtained. The Harpers phyllite is overthrust upon the limestone. If this water comes from the limestone it is unusually low in total dissolved solids. (See analysis No. 47). The limestone is an uncertain water horizon and the yield of a well is dependent upon its encountering water-bearing solution channels. (Nos. 45 to 49).

The Ordovician and Cambrian limestones are overlain by rocks of Triassic age. The Stockton formation, the basal division of the Upper Triassic, is well exposed in East and West Norriton and part of Upper Merion townships. Small supplies can be obtained from this formation at depths of 150 feet or less, and larger supplies can be developed by drilling deeper. (Nos. 50 to 71). The Pennsylvania State Hospital for the Insane, in the northern part of Norristown, obtains its supply from nine drilled wells (Nos. 52 to 60). These wells are all pumped with compressed air through a 1½-inch air line. The average working air pressure is 75 pounds per square inch. The water from seven of the wells is pumped into a 500,000 gallon concrete reservoir, from which it is distributed by gravity. The average daily consumption is 750,000 gallons, by 3,500 persons, or a per capita consumption of 215 gallons. A well at the Peoples Sanitary Dairy, Norristown, (No. 61) yields 100 gallons a minute with a drawdown of 90 feet. The well was started 10 inches in diameter, but was reduced to 8 inches at 110 feet below the surface. A little water was encountered between 100 and 110 feet, but was cased out with the 10-inch casing. Water enters the well at 350 feet at the rate of 45 gallons a minute. More water enters the well between 708 and 731 feet, but the exact amount was not determined. The water rises within 63 feet of the surface.

The Stockton formation is overlain by the Lockatong formation, which is a poor water horizon, but in most places supplies of 1 or 2 gallons a minute or more can be developed. (Nos. 72 to 75). Large supplies are difficult to obtain.

The Lockatong formation is overlain by the Brunswick shale. Three wells and a spring (Nos. 76 to 79) in Hilltown Township, Bucks County, supply the borough of Souderton. The wells are in the Brunswick shale, but the spring issues from the Lockatong formation. The spring water is reported to be much softer than the well water. There are three wells (Nos. 82 to 84) within 150 feet of each other on the property of George Alexander, in Colmar. Evidently the water in these wells comes from different horizons with different static heads. The Brunswick shale usually yields small supplies to drilled wells ranging from 50 to 250 feet in depth, but in most places large supplies can be obtained only by drilling several wells. (Nos. 76 to 84).

A few small areas of the Patapsco formation and some small patches of terrace gravels, probably Sunderland formation, are found in this area, but they are unimportant as ground-water horizons.

Montgomery, Upper and Lower Gwynedd, Whitepain, Whitemarsh, and Lower Merion townships. The oldest formation outcropping in the area included in these townships is the Baltimore gneiss. This formation is at the surface over a considerable part of Lower Merion and Whitemarsh townships. In most places small supplies ranging from 1 to 10 gallons a minute can be obtained from drilled wells which range from 50 to 250 feet in depth. However, some wells may be failures. Wells yielding more than 25 gallons a minute are rare.

The Baltimore gneiss is overlain by the Wissahickon formation. A number of successful wells have been drilled in this micaceous rock. (Nos. 85 to 90f). The six wells in Lower Merion Township (Nos. 90a to 90f) yield more water than most wells in the Wissahickon formation. The well of Mr. Mitchell near the mouth of Mill Creek overflows. The well evidently cuts fissures which contain water under pressure.

The Wissahickon formation is overlain by the Chickies quartzite. This rock usually forms ridges on account of its greater resistance to erosion. In most places small supplies can be developed by drilling wells 250 or 300 feet deep, but failures to obtain water may occur.

The Chickies quartzite is overlain by the limestones of Cambrian and Ordovician age which are more easily eroded than the surrounding rocks and therefore form the valleys. The Ambler Spring Water Co. obtains its supply from a spring in a quarry at Whitemarsh. The spring apparently is fed by larger water-bearing solution channels. The water is very clear, but it is necessary to chlorinate it. (See analysis No. 95). The rock is a dolomite, with a strongly developed platy cleavage that dips at a high angle. The irregular contact of dolomite and soil was well exposed in this quarry at the time of the writer's visit (September, 1925), because the soil had recently been removed from a considerable area preparatory to quarrying the rock. The pump house is directly over the spring which is in a pit in the quarry about 50 feet below the surface. In this house are three 1000-gallon a minute Cameron pumps, two of which are driven by 40-horsepower electric motors, and one by a 40-horsepower gasoline engine. The two electrically driven pumps are ordinarily used, and the gasoline-driven one is used only in emergencies. The average daily yield of the spring is 600 gallons a minute. The water is pumped to a 200,000 gallon tank at Broadaxe by two other pumps, and is distributed by gravity to Ambler and the vicinity. Five 20,000 gallon tanks in the tower at the east side of Ambler are filled from the Broadaxe tank. The large yield of this spring and also one of the wells (No. 94) indicates the presence of water-bearing solution channels in the limestone.

The Triassic deposits rest unconformably upon the older formations in this area. The Stockton, the oldest Triassic formation, crosses Lower Gwynedd and Whitpain townships. It is an excellent water horizon and adequate domestic supplies can usually be obtained. (Nos. 96 to 98b).

The Stockton formation is overlain by the Lockatong formation, which is a less favorable water horizon. The North Wales Water Co. supplies the borough of North Wales with water obtained from wells (Nos. 101 to 108). Well No. 1 is on a hill east of the borough. This well, now abandoned, was pumped by a windmill. It was shot but the yield was not increased. Well No. 2 is under the office of the com-

pany and No. 3 is in the rear of the office. When pumped simultaneously, wells Nos. 2 and 3 interfere with each other. Well No. 4, beside the firehouse, has filled in with about 6 feet of sand. When originally tested during a wet period it yielded 100 gallons a minute. Its maximum yield is now 70 gallons a minute, but it is usually pumped at a rate of 50 gallons a minute. Pumping at 70 gallons a minute causes the water to drop below the end of the pump intake 148 feet below the surface. Well No. 5, situated 300 feet distant from No. 4, was a failure. It was dry and water had to be poured in the hole for drilling. These five wells were drilled in the Lockatong formation. Well No. 6, at 9th Street and Montgomery Avenue, 2,200 feet from the office, was pumped at the rate of 20 gallons a minute but it soon sucked air. The yield, with about a 20-foot drawdown, is 5 gallons a minute. Well No. 7 is on Elm Avenue about 2,400 feet from the office. Well No. 8 is on Walnut Street about 300 feet from No. 7. Although these three wells start in the Brunswick shale, it is probable that No. 6 is in the underlying Lockatong formation from 100 to 400 feet. The Lockatong formation is not a satisfactory water horizon, and although domestic supplies can usually be developed, difficulty is frequently experienced in obtaining large supplies.

The Lockatong formation is overlain by the Brunswick shale. The Lansdale Water Co. supplies Lansdale with water obtained from wells. Three wells at the plant are closely spaced although it is reported that pumping one of them does not affect the water level in the other two. These three wells obtain their water from a zone between 225 and 350 feet below the surface. A composite sample of the water from five wells Nos. 111 to 113, was collected. (See analysis No. 111). Another well (No. 114) located in West Lansdale, during wet seasons may yield 100 gallons a minute. The wells are pumped with an air lift except the West Lansdale well which is pumped by a deep-well pump driven by an electric motor. The water from the last named well is pumped directly into the mains, but the water from the others is pumped to reservoirs from which it is distributed by gravity. Smaller supplies can be obtained from the Brunswick shale by drilling wells ranging in depth from 50 to 250 feet. (Nos. 115 to 117). The well at the Lansdale Electric Light Co.'s plant, when pumped at the rate of 90 gallons a minute, had a drawdown of 80 feet in 12 minutes.

Several small areas of the Patapsco formation, of Lower Cretaceous age and some sand and gravel beds of Quaternary age are found in Lower Merion, Whitemarsh, and Plymouth townships. These areas are too small to be of importance as sources of ground water.

There is an area of hornblende gneiss in the southern part of Lower Merion Township. This rock resembles the Baltimore gneiss in its water-bearing properties.

The Baltimore gneiss has been intruded by gabbro, and several of these intrusive masses are exposed in Lower Merion Township. Gabbro is a poor ground-water horizon, and most wells drilled in this rock yield very small supplies.

Several serpentine areas occur in Lower Merion Township. Serpentine is usually thoroughly fractured and jointed and wells yield small supplies of rather highly mineralized water.

Diabase dikes are not numerous in this area. The water-bearing properties of this rather impervious rock are discussed under preceding groups of townships.

Horsham, Upper Dublin, Springfield, Upper and Lower Moreland, Abington, and Cheltenham townships. The oldest rock exposed in these townships is the Baltimore gneiss, which is the surface formation in parts of all of these townships except Horsham. This formation is the basement rock of the region. Wells drilled in it usually obtain small supplies at depths of less than 250 feet. Some few wells may yield 50 gallons a minute, or more.

The Baltimore gneiss is overlain by the Wissahickon formation. The Moreland Spring Water Co. has eight wells near Bethayres, which are used as a reserve when the flow of Pennypack Creek is diminished by drought. (Nos. 120a to 120h). These wells are pumped simultaneously by a steam siphon. Although a number of wells yield more than 50 gallons a minute, wells which yield from 1 to 10 gallons a minute are much more common. Anyone drilling into the schist and the gneiss of this formation should not be too sanguine of obtaining supplies of 50 gallons a minute, or more.

The Wissahickon formation is overlain by the Chickies quartzite. The Chickies is a somewhat uncertain ground-water horizon because some wells are failures. (Nos. 125, 126). However, small supplies can usually be developed. The water from the quartzite is usually very low in dissolved mineral matter.

The Chickies quartzite is overlain by the Cambrian and Ordovician limestones. The water-bearing properties of the limestones are discussed under the preceding group of townships.

The older rocks are overlain uncomformably by Triassic rocks. The basal Stockton formation is well developed in this area. The Hatboro Water Co. supplies Hatboro with water obtained from two drilled wells (Nos. 130, 131) situated in the eastern part of the borough. Both of these wells have yielded on a test 170 gallons a minute for several hours. They are pumped by American Water Works deep-well pumps belt driven by electric motors with fuel-oil engines in reserve. The water is chlorinated and pumped to a standpipe 100 feet high and 20 feet in diameter, capacity 235,000 gallons, from which it is distributed by gravity at pressures ranging from 35 to 55 pounds per square inch. A sample of water was taken from well No. 1. (See analysis No. 130). Wells which fail to yield water are not numerous in the Stockton formation.

The Stockton formation is overlain by the Lockatong formation, which outcrops in the extreme northwestern part of Horsham Township. The water-bearing properties of this formation are discussed under the preceding group of townships.

Gabbro intrusions in the pre-Cambrian rocks have been exposed by erosion in several places. Gabbro is a poor water horizon and many wells yield little or no water. (No. 132).

DRILLED WELLS IN MONTGOMERY COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formations	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1	Rudolph Gurtzen	1 mile N. of Kleinville	125	6	Brunswick shale	50	10	
2	A. F. Butterwick	Hoppenville	107	6	do		1	
3	Frank Mack	½ mile SW. of Hoppenville	67	6	do		8	
4	William R. Miller	1 mile W. of East Greenville	68	6	do		15	
5	John Latshaw	Niantic	125	6	do		10	Other wells in vicinity similar.
6	Cyrus Lutz	1 mile NW. of Congo	100	6	do		10	
7		New Hanover	60-100	6	do		15-20	A number of wells.
8	Mr. Lessig	¼ mile S. of Eagleysville	100	6	do		6	
9	Schwenkville Water Co.	Schwenkville	300	6	do	92	85	Drawdown 60 feet.
10	Mr. Poley	Limerick	125	6	do		30	
11	School House	do	110	6	do	30	15	See analysis.
12	Abe Brockerman	1 mile W. of Limerick	85	6	do	25	7	Water enters at 40 feet; small drawdown.
13	Garrett-Brombach Creamery	Linfield	300	6	do		200	Pumping affects water level in other wells in Linfield.
14	Mr. Shaner	Sanatoga	125	6	do		1½	Large drawdown.
15		do	150-280	6	do		10	Large number of wells.
16		do	135	6	do	50	4	Water enters at 40 feet.
17	Mr. Satterwaite	do	175	6	do		25	
18	Mr. Buckwalder	¼ mile E. of Pottstown	100+	6	do		15	
19	Pottstown Cold Storage Co.	Pottstown	618		do	50	120	
20	A. Printz	do	125	6	do		15	Used for cooling.
21	Warwick Iron Co.	do	210-225	10	do	30	100	Five wells in creek.
22	do	do	450	10	do	80	250	Three wells in slag pile.
23		Glasgow	125±	6	do		5	Numerous wells.
24		Ringing Rock Park	90	6	Diabase		3	
25		Oaks	90	6	Stockton formation		5	Numerous wells.
26	Carl Thompson	1 mile N. of Valley Forge	96	6	do		7	Brown sandstone.
27	F. Kitchen	do	86	6	do		6	Brown sandstone.
28	Baptist Church	Eagleville	135	6	Lockatong formation	25	3	
29	Eagleville Sanatorium	do	511	6	do		9	Dry in lower 300 feet.
30	do	do	490	6	do		11	Dry in lower 300 feet; see analysis.
31	Mr. Reese	do	106	6	do	3	5	Water enters at 52 feet.
32	Lower Providence Presbyterian Church	do	245	6	do		¾	
33		1 mile SW. of Skippac	112	6	Brunswick shale	25	4	Water enters at 65 feet; large drawdown.

34	----	Tylers port	69	6	do	----	10	
35	John McConnell	1 mile NE. of Collegeville	111	6	do	20	40	Water enters at 111 feet; drawdown 10 feet; conglomerate encountered at bottom.
36	Norman Bowers	Collegeville	93	6	do	----	6	Below blue rock.
37	John Andrews	do	93	6	do	----	6	Only 15 feet from No. 36.
38	Rev. Herbert Howell	do	93	6	do	30	3	Water enters at 55 feet.
39	Mr. Kundt	do	81	6	do	35	8	Water enters at 50 feet; drawdown 7 feet.
40	A. Pearlstein	do	60	6	do	18	7	
41	S. R. Reiff	do	111	6	do	50	4	Water enters at 65 feet; large drawdown; see analysis.
42	Dr. Addis	Lower Providence	125	6	do	----	4	
43	Montgomery County Home*	2 miles SE. of Royersford	208	8	do	90	120	
44	George R. Park	1 mile S. of King of Prussia	250	6	Wissahickon formation	----	8	
45	Diamond State Fibre Co.	West Conshohocken	658	8	Limestone	----	Dry	
46	Titus and Taylor	do	200	8	do	----	do	
47	T. J. Kirkpatrick	1 mile SW. of Norristown	186	6	do	152	5	Top of high hill; see text and analysis.
48a	Valley Forge Mfg. Co.	½ mile E. of Port Kennedy	200	6	do	15	100	
	Well No. 1	do	200	6	do	15	100	
48b	Well No. 2	1 mile SE. of Valley Forge	700	6	do	----	80	Flowed when completed.
49	Ehret Mfg. Co.	½ mile W. of Bridgeport	385	6	Stockton formation	----	10	
50	Tabak & Lenhardt	Penn Square Race Track,						
51	----	N. of Norristown	35–132	6	Stockton formation	----	3–30	Twenty wells; average depth about 65 feet.
52	State Hospital for the Insane, Well No. 1	Norristown	410	10	do	136	178	Near reservoir; air line 319 feet long; see analysis.
53	Well No. 2	do	407	10	do	136	120	Near reservoir; air line 311 feet long.
54	Well No. 3	do	400	8	do	121	170	do; air line 294 feet
55	Well No. 4	do	448	8	do	136	205	do; air line 307 feet
56	Well No. 5	do	486	8	do	129	170	do; air line 295 feet
57	Well No. 6	do	427	8	do	129	180	do; air line 301 feet
58	Well No. 7	do	401	10	do	141	170	do; air line 301 feet
59	Well No. 8	do	277	8	do	61	110	At Power House; air line 240 feet long; see analysis.
60	Well No. 9	do	321	8	do	53	192	do; air line 262 feet
61	People's Sanitary Dairy	do	731	10–8	do	63	100	See text.
62	----	do	169	6	do	----	15	
63	----	do	102	6	do	----	17	
64	----	do	100	6	do	----	50	

No.	Owner	Location	Depth	Diameter	Water-bearing formations	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
65	Charles Meyers	Norristown	65	6	Stockton formation		10	
66		West of Norristown	75	6	do		25	
67	F. A. Potts	Jeffersonville	92	6	do		20	
68		Near Hickorytown	70	6	do		10	
69	Sandy Hill School House	Whitpain Township	60	6	do		2	
70		Washington Square	35	6	do		25	
71	School House	do	38	6	do		10	
72	Reading Co.	Belfry Station	37	6	Lockatong formation		½	Abandoned.
73		½ mile NW. of Belfry	265	6	do		2½	
74	Community Hall	Fairview Village	58	6	do		1	Blue rock.
75		Between Providence Square and Fairview Village	50–150	6	do		3–5	Brown sandstone, black and brown shale.
76	Souderton Water Works	Souderton	1,100	6	Brunswick shale		2	Flows 2 g.p.m. at elevation of plus 6 inches.
77	do	do	500	6	do		30	
78	do	do	216	10	do		100	
79		Hatfield	100	6	do		10+	Numerous wells.
80		1½ miles E. of Hatfield	75	6	do		10	
81		Colmar	75–100	6	do		10+	Numerous wells.
82	George Alexander	do	72	6	do	30	14	18-feet of casing.
83	do	do	154	6	do	90	8	35 feet of casing.
84	do	do	47	6	do	20	15	27 feet of casing.
85	Barrett Ice Plant	Bryn Mawr	752		Wissahickon formation		10	
86	do	do	475		do		60	
87	Bryn Mawr Hospital	do	135		do		5	
88	Bryn Mawr Hotel	do	350	10	do		50	
89	Springfield Water Co.	do	560	6	do		83½	
90	Bryn Mawr Radnor Hunt Club	Near Bryn Mawr	124	6	do		12	
90a	Percival E. Foerderer	1½ miles S. of Conshohocken	37	8	do	12	25	Drawdown 25 feet.
90b	do	do	300	8	do	12	130	Drawdown 200 feet.
90c	do	do	400	8	do	45	60	do
90d	J. Kearsley Mitchell	1 mile S. of Conshohocken	300	6	do	6	175	Drawdown 40 feet.
90e	do	do	300	10	do	6	175	do
90f	Rodman Miscom	3 miles SE. of Conshohocken	300	8	do	0	30	Drawdown 200 feet, will flow a few g.p.m.
91		Near Williams Station	132		Chickies quartzite		5	
92	Kunkle Farm	Near Flourtown	60		Limestone		83½	
93		Near Plymouth Junction	90		do		40	

94	Thomas Phipps	Near Williams Station	40		do		900	
96	Lower Gwynedd Consolidated School	Spring House	130	6	Stockton formation		20	Red sandstone and shale
97	H. Ingersoll	½ mile N. of Penllyn	150	6	do		45	
98a		Between Belfry and Blue Bell NW. of Center Square	75–130	6	do		10–30	
98b		do SE. of Center Square	45–100		do		5–50	Formation contains more sandstone than at No. 98a.
99	John Wright	Montgomery Square	80	6	Lockatong formation	11	15	Drawdown 30 feet; very hard rock; water enters at 65 feet; see analysis.
100		do	139	6	do		1½	Near to No. 99.
101	North Wales Water Co. Well No. 1	North Wales	500	6	do		5	
102	Well No. 2	do	130	6	do		50	
103	Well No. 3	do	125	6	do		50	
104	Well No. 4	do	157	6	do		50	See analysis.
105	Well No. 5	do	300	6	do			Dry hole.
106	Well No. 6	do	400	10	do		5	
107	Well No. 7	do	400	8	Brunswick shale		90	See analysis.
108	Well No. 8	do	450	10	do		60	
109	G. Stout	Montgomeryville	75	6	do	35	8	Water enters at 50 feet from brown sandstone.
110	Lansdale Water Co.	Lansdale	325	8	do		30	Two wells. Abandoned.
111	do	do	325–1,100	8	do		65	Three wells at plant; see analysis and text.
112	do	do	500	8	do		65	1,100 feet south east of plant.
113	do	do	310	8	do		65	do
114	do	West Lansdale	300	8	do		85	
115	Lansdale Electric Light Co.	Lansdale	300	8	do	45	38	Red shale.
116	Frank Weaver	do	111	6	do	10	45	Water enters at 108 feet; drawdown 3 feet; 2 g.p.m. depth of 30 feet.
117		do, near No. 116	122	6	do	9	4½	Water enters at 120 feet; 1 g.p.m. depth of 34 feet.
118	James Shields	Rockledge	60	6	Wissahickon formation	14	20	Drawdown 26 feet.
119		Jenkintown	349	6	do		75	
120a	Moreland Spring Water Co., Well No. 1	Bethayres	154	6	do		97	
120b	Well No. 2	do	205	6	do		60	
120c	Well No. 3	do	212	6	do		76	
120d	Well No. 4	do	188	6	do		70	

No.	Owner	Location	Depth	Diameter	Water-bearing formations	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
120e	Well No. 5	Bethayres	147	6	Wissahickon formation		78	
120f	Well No. 6	do	235	6	do		30	
120g	Well No. 7	do	175	6	do		50	
120h	Well No. 8	do	200	6	do		28	
121		Near Jenkintown Station	324	6	do		75	
122		Cheltenham Academy	352	6	do		12	
123		Chelten Hills Station	118	6	do		3	
124		Noble Station	163	6	do		16	
125		Edge Hill	570	6	Chickies quartzite		Dry	
126		Willow Grove	780	6	do		100	
127	Mrs. Miller	Near Prospectville	245	6	Stockton formation		½	Blue and black shale resembling the Lockatong formation.
128	L. J. Claire	1½ miles N. of Horsham	137	6	do		15	
129	Isaac Warner	Horsham	107	6	do		12	Red shale and sandstone
130	Hatboro Water Co.,							See analysis.
	Well No. 1	Hatboro	300	6	do		135	
131	Well No. 2	do	250	6	do		135	
132	Mr. Johnson	Sorrelhorse	75	6	Gabbro		5	
	State Penitentiary	Graterford						
	Well No. 1, outside	do	500	10	Brunswick shale	80	150	
	2, inside	do	552	10	do	143	165	
	3, inside	do	497	10	do	143	155	
	4, inside	do	596	10	do	141	163	

NORTHAMPTON COUNTY

GENERAL CONDITIONS

Northampton County is bounded by Delaware River, which separates it from New Jersey, and by Bucks, Lehigh, Carbon, and Monroe counties. The top of Kittatinny Mountain is the boundary between Northampton and the last two named counties. The area of the county is 372 square miles, and the population 169,304 according to the United States Census of 1930. The average number of inhabitants per square mile is 455.1, while the average for the entire State is only 214.8. The percentage of urban population is 68.2 per cent. The density of rural population is 131 per square mile. The county contains the cities of Bethlehem and Easton, as well as a number of smaller incorporated and unincorporated towns. It is a highly industrialized area in which are located great steel and cement mills and numerous other manufacturing plants and textile mills.

GEOLOGY OF NORTHAMPTON COUNTY

The geology of Northampton County resembles that of Lehigh County, except that the northeastern part of Northampton County is covered with glacial drift, and that the Triassic sediments, so prominent in the southern part of Lehigh County, are missing.

Geologic column of Northampton County[1]

Age	Name and description	Thickness	Water-bearing properties
Quaternary	Glacial deposits. Chiefly till. A heterogeneous deposit of sand, clay, gravel, and boulders.	0–50	Small yields, chiefly from shallow dug wells.
Ordovician	Martinsburg shale. Blue-black shales, in part metamorphosed to slate, and greenish-gray sandstone.	11,000	Some excellent wells, some poor wells in slate. Shale wells usually small producers.
	Leesport "cement rock." Dark argillaceous limestone, cut by veins of quartz and calcite.	500±	A rather poor water-bearing formation.
	Jacksonburg limestone. Pure limestone.	75	Limestone yields larger supplies than "cement rock."
	Beekmantown limestone. Blue-gray dolomite limestone, more massive below and thinner bedded above.	1,000±	Large yields are obtained from cavernous rock, but solid limestone yields little or no water.
Upper Cambrian	Conococheague limestone. Thin to thick-bedded limestone with some siliceous limestones and thin shales.	1,500±	Large yields from cavernous rock, but some wells yield little or no water.
	—Probable unconformity —		
Lower Cambrian	Tomstown dolomite. Limestone interbedded with shaly limestones. High in magnesium carbonate.	1,000±	Most wells yield small supplies.
	Hardyston quartzite. Sandstone, quartzite, and conglomerate.	20–300	Small yields but some supplies up to 50 gallons a minute may be obtained.
Pre-Cambrian	Gneiss of different types and probably of both igneous and sedimentary origin.		Small supplies at depths not exceeding 250 feet.
	Gabbro. Granite and associated rocks.		A poor water-bearing rock, yields small supplies.

[1] Behre, C. H., Jr., Slate in Northampton County, Pennsylvania: Pennsylvania Top. and Geol. Survey, 4 ser., Bull. M9, pp. 10–34, 1927.
Miller, B. L., Mineral resources of the Allentown quadrangle: Pa. Top. and Geol. Survey, Atlas No. 206, 1925.

The formations mentioned in the geologic column are described and their water-bearing properties discussed in the introductory pages.

TOWNSHIP DESCRIPTIONS

Upper and Lower Mount Bethel and Washington townships. The oldest formation outcropping in the area covered by these townships is the Beekmantown limestone, which is exposed along Delaware River. Two drilled wells of the Lehigh Portland Cement Co., 1½ miles south of Martins Creek, are both strong wells (Nos. 1a and 1b). The first 70 feet is sand and gravel which was cased out, and the remainder is drilled in limestone. The drawdown is only 5 feet. There is, however, no assurance that wells in other localities will be equally productive.

Data are not available on wells drilled into the Leesport "cement rock" and Jacksonburg limestone in this area. The Martinsburg shale in this area has largely been metamorphosed to slate. It contains sandstone which may yield water in the deeper wells (See well No. 2). Several drilled wells in Mount Bethel range in depth from 55 to 100 feet (Nos. 3a to 3d). These wells end in slate, although they pass through glacial deposits. The average yield is 6 gallons a minute. The borough of Bangor has a number of drilled wells along the flank of Kittatinny Mountain, north of the town, most of which overflow all or part of the year.

Drilled wells of Bangor Water Company

No.	Name	Depth Feet	Yield g.p.m.	No.	Name	Depth Feet	Yield g.p.m.
1	----------	500	250	6	Riley ----------	180	200
2	----------	146	100	7	Althofer ----------	260	100
3	----------	138	100	8	Offset Hollow ----------	120	50
4	Le Bar ----------	114	250	10	----------	570	20
5	Hofflet ----------	----------	1–100				

During very wet spells the flow of well No. 2 increases to 250 gallons a minute. When well No. 2 is open the flow of No. 3 is greatly diminished. Well No. 5, called the Hofflet well, flows for six months a year from 1 to 100 gallons a minute and is pumped by an air lift for the remainder of the year. In dry weather No. 8 well ceases flowing and is pumped at the rate of 250 gallons a minute with a 20-foot drawdown. Well No. 9 was not a success. Well No. 10, (No. 4a in table), at the reservoir in Roseto, yields 20 gallons a minute with a 100-foot drawdown. See analysis No. 4b.

Glacial deposits cover most of this area except the southern parts of Lower Mount Bethel and Washington townships. The Wisconsin terminal moraine forms a series of almost continuous ridges across these townships. In addition to the terminal moraine, the ground moraine is well developed and in the vicinity of Portland there is a large outwash plain. The terminal moraine makes the most striking topographic feature but the other deposits are of greater importance as sources of water. The ground moraine consists of clay with boulders up to 3 feet in diameter which are scattered throughout the clay with no arrangement according to size. In places this material is somewhat sandy and yields some water. The outwash plain consists mainly of gravel, sand, silt, and clay in thin layers of limited and irregular

extent. Where not too fine-grained the outwash plains are frequently excellent sources of water. In this area the glacial deposits are, except along the flanks of Kittatinny Mountain, too thin and too thoroughly dissected by post glacial drainage to be of great importance as sources of water. Along the flanks of Kittatinny Mountain the glacial drift has been more or less intermingled with talus and it is difficult to determine how much of the debris is talus and how much is drift. A number of springs issue from the drift along the mountain. Among the more important are the Handelong, Althofer, and Muffley springs, which yield, respectively, 350, 250, and 200 gallons a minute. A sample of the water from the Muffley Spring was collected. (See analysis No. 10). Apparently in this area the water from the glacial drift contains more dissolved mineral matter and is harder than the water from the slate. The borough of East Bangor has three wells (Nos. 11a, b, and c). The driller reports that these wells are all drilled in loose material. The flow can possibly be explained by figure 7. The water enters the base of the till near the top of the mountain and works its way along the contact of the till and the slate, and when penetrated rises in the wells and overflows. The flows encountered in the Bangor wells may come from this horizon and not from the slate. A number of wells have been dug in the outwash plain at Portland and are successful at shallow depths but difficulties are experienced with quicksand. The wells given in the table (Nos. 12 and 13) end in quicksand and were somewhat difficult to finish. Where the glacial deposits are thick large supplies are obtainable and along the flanks of Kittatinny Mountain from the Big Offset to Delaware River flows can be obtained. Where the glacial deposits are thin small yields can be obtained. In many places, however, the till is only 5 or 10 feet thick, and wells must obtain their supplies from the underlying rocks.

Plainfield and Bushkill townships. The only formation outcropping in these townships is the Martinsburg shale, which is largely metamorphosed to slate. In places it is covered with glacial deposits. West of Wind Gap the glacial deposits are thin or wanting, but the slopes of Kittatinny Mountain are deep with talus. The Blue Mountain Water Co. has several wells at Pen Argyl drilled through the drift into the underlying slate (Nos. 17, 18a, 18b). The 10-inch drilled well at the Lehigh & New England Railroad shops near Pen Argyl (No. 19) is 450 feet deep and yields 150 gallons a minute with a drawdown of 25 feet. The well was drilled through 80 feet of till and 370 feet of slate. The Blue Mountain Water Co. has several wells drilled in the slate beside an abandoned slate quarry. The quarry was once used as a source of water but due to contamination from the surface is no longer used. An 8-inch drilled well 400 feet deep situated beside the quarry (No. 22) yields 150 gallons a minute. When not pumping this well flows a few gallons a minute. This flow is obviously from the slate, as glacial deposits are lacking. (See analysis No. 22). Another well, now abandoned, is 600 feet deep and yielded only 30 gallons a minute, although the water rose to the surface. These wells indicate that the slate in places yields considerable volumes of water. Some wells, however, are failures. (For wells of the Blue Mountain Water Co. at Wind Gap and Nazareth see Nos. 20 to 24 in table, for analyses of 3 of the waters see Nos. 20-24). Domestic supplies are available in

most places at depths of less than 150 feet but in some localities it may be necessary to drill 200 feet, or more, to obtain as much as 3 gallons a minute.

On the flanks of Kittatinny Mountain from Pen Argyl to the Wind Gap there are thick deposits of glacial drift and talus from the overlying quartzite. These materials yield considerable water. Springs are used for supplying Pen Argyl, but due to fluctuations during dry spells they must be supplemented by wells.

West of the Wind Gap the amount of drift is negligible, but the mountain side is covered with talus from which a number of springs issue. These springs are usually small and show great seasonal fluctuations. Many of them dry up during prolonged drought.

Palmer and Forks townships. The oldest formations outcropping in these townships are the gneisses, schists, and serpentines of pre-Cambrian age. The small springs in the talc and serpentine quarry of C. K Williams & Co. yield less than 2 gallons a minute. (See analysis No. 26). The pre-Cambrian rocks are of several types, but all are thoroughly metamorphosed and will probably not yield large supplies to wells drilled in them. However, supplies adequate for domestic use can be obtained in most localities. The Hardyston quartzite, which usually overlies the gneiss and associated rock, is not present in large enough masses to be of any importance as a ground-water horizon.

The crystalline rocks are overlain in most places by limestones of Cambrian and Ordovician age. (For wells drilled into these rocks see Nos. 27-32). A spring on the property of Mrs. Leona Johnson, 2 miles northwest of Easton, yields 150 gallons a minute. (See analysis No. 29).

Upper and Lower Nazareth townships. The oldest rocks exposed in these townships are the Cambrian and Ordovician limestones. The two drilled wells at the Dexter Portland Cement Co., near Nazareth (Nos. 33a, 33b) each yield 150 gallons a minute with a 70-foot drawdown. The wells were both started 12 inches in diameter and reduced to 8 inches. These wells indicate that large supplies can be obtained from the limestone, but one should not be too optimistic because wells in solid limestone rarely yield much water.

Bethlehem, Lower Saucon, and Williams townships. The oldest rocks outcropping in these townships are the schist, gneisses and crystalline limestone of pre-Cambrian age. The schists and gneisses form hills while the limestones form valleys. No data on wells drilled in these rocks are available, but experience in adjacent areas indicates that supplies of 1 to 5 gallons a minute can usually be obtained but that large supplies are rarely obtainable.

The pre-Cambrian rocks are overlain by the Hardyston quartzite, which has numerous outcrops in Lower Saucon and Williams townships. Few wells have been drilled in the quartzite, but apparently small supplies are obtainable (See No. 34). Somewhat larger supplies should be available at the contact of the quartzite and the underlying pre-Cambrian rocks.

The Hardyston quartzite is overlain by limestones of Cambrian and Ordovician age which supply many wells, some of which produce large quantities of water (Nos. 35 to 61). The city of Bethlehem has a

well 1,012 feet deep about 1 mile north of the city (No. 42a). It was started 15 inches in diameter and passed through 11 feet of clay into Conococheague limestone. It was then reduced to 12 inches, and at 800 feet it was reduced to 8 inches. The well flows 150 gallons a minute and yields with a suction pump 1,450 gallons a minute. Numerous openings were encountered in the limestone and water enters the well at a number of places. (See analysis No. 42a).

The city of Bethlehem formerly had a 300-foot well in the city near the river from which 312 gallons a minute were pumped (No. 43). The well is now abandoned. A large spring in the city was used, and furnished water for the first waterworks in Pennsylvania[1] but the spring has been abandoned on account of contamination. The well of the Bethlehem Silk Co., Bethlehem, (No. 45) is 400 feet deep and yields 900 gallons a minute. The water rises within 10 feet of the surface and the drawdown is less than 15 feet. The 10-inch well drilled at the Myer Herberger Dairy (No. 48), Bethlehem, is 171 feet deep and yields 150 gallons a minute with a 10-foot drawdown. The city also has two additional wells nearby which are 8 inches in diameter and are 700 and 750 feet deep (Nos. 42b, 42c), respectively, and yield 800 gallons a minute each. The South Easton Water Co. has two drilled wells in South Easton along Lehigh River which are 80 and 350 feet deep and have a combined yield of 850 gallons a minute (Nos. 51a, 51b). The Bethlehem Steel Co. has several wells at its coke plant. One well is 353 feet deep and yields 700 gallons a minute (No. 57). Another well (No. 58) was drilled 10 feet from the first and at a depth of 150 feet broke into it. It yields 500 gallons a minute. About 300 feet away there is a very similar pair of wells (Nos. 59a, 59b). The 6-inch drilled well at the Park Hotel in Hellertown is 106 feet deep and yields 300 gallons a minute (No. 61). The yields of these wells indicate that large supplies can be obtained but that some wells will be dry. In this area some deep wells, such as the 1,012 foot well of the city of Bethlehem, are very productive. In many areas deep drilling has not yielded such favorable results.

Lehigh and Moore townships. The only formation outcropping in these townships with which this report is concerned is the Martinsburg shale. A 4-inch drilled well of the borough of Bath is 225 feet deep and a considerable volume of water flows out through a pipe sunk 20 feet beneath the surface. The shale, which in most places is metamorphosed to slate, yields considerable quantities of water. In general wells obtain their supplies in the first 300 feet beneath the surface. Due to the complexity of the structure and poor outcrops, areas in which flowing wells can be expected can not be accurately outlined.

Allen, East Allen, and Hanover townships. The oldest formation outcropping in Allen, East Allen, and Hanover townships is a mass of pre-Cambrian rocks which form a westward extension of the Pine Top-Quaker area. These rocks are unimportant as a source of ground water.

The pre-Cambrian rocks are overlain by the Hardyston quartzite, which in some areas yields moderately large supplies and should yield supplies adequate for domestic use but large yields can not be predicted.

[1] Water Supply Commission of Pennsylvania, Water Resources Inventory Report, Part VI, p. 2, 1920.

The Hardyston quartzite is overlain by the Tomstown dolomite, the Conococheague, Beekmantown and Jacksonburg limestones, and the Leesport "cement rock" in the order named. The borough of Siegfried has three drilled wells. The deepest one, 300 feet deep, yields more than 100 gallons a minute. The others are each 200 feet deep and have a combined yield of 450 gallons a minute.

The Leesport "cement rock" is overlain by the Martinsburg shale, now metamorphosed to slate, in which the borough of Bath has several drilled wells (No. 67).

DRILLED WELLS IN NORTHAMPTON COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
1a	Lehigh Portland Cement Co.	1½ miles S. of Martins Creek	160	10	Beekmantown limestone	60	200	Water enters near bottom.
1b	do	do	155	10	do	60	200	do
2	L. Pottsman	2½ miles N. of Johnsonville	80	6	Martinsburg shale		15	"Slate".
3a		Mount Bethel	55	6	do		6	
3b		do	65	6	do		6	
3c		do	70	6	do		6	
3d		do	100	6	do		6	
4a	Bangor Water Company	Bangor	570		do	100	20	
4b	do	do	500	10	do		250	Water level several feet below surface; see analysis.
5	do	East Bangor	117	6	do		½	Hard "slate".
6	Levi Beck	Centerville	80	6	do		5	Well is 8 inches in diameter at top, end in "slate".
7	Joseph Thompson	1 mile W. of Centerville	100	6	do	8	10	
8		1½ miles NW. of Richmond	150	6	do		10	"Slate".
9		Ackermanville	85	6	do		5	do
11a	Borough of East Bangor	East Bangor	126	8	Glacial drift (?)		150	Flows.
11b	do	do	125+	8	do (?)		100	do
11c	do	do	125+	8	do (?)		100	do
12		Near Portland	70	6	do		6	"Quicksand".
13		do	34	6	do		3	do
14	The Candy Kitchen	Bangor	50	6	do		10	Sand and gravel.
15	Weiss Coal & Lumber Co.	do	60	6	do		10	do
16		1¾ miles WSW. of Centerville	65	6	do		3	
17	Blue Mountain Water Co.	Pen Argyl	450	6	Martinsburg shale	100	80	Water enters at 250 feet.
18a								
18b	do	do	200	8	do		25	Two wells; yield 25 gallons a minute each.
19	L. & N. E. Railroad		450	10	do	15	150	"Slate"; water enters at 250 feet.
20	Blue Mountain Water Co.	Wind Gap	150	8	Glacial drift and talus		150	See analysis.
21a		Delabole	100	6	Martinsburg shale		3	"Slate".
21b			107	6	do		4	do
22	Blue Mountain Water Co.	Nazareth	400	8	do		150	Some hydrogen sulphide; flows a few gallons a minute; see analysis.

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
23	Blue Mountain Water Co.	Nazareth	325	8	Martinsburg shale		150	See analysis.
24	do	do	130	8	do		150	Flows 10 gallons a minute; see analysis.
25	John Ruth	2 miles NE. of Easton	50	6—	Pre-Cambrian gneiss	25	15	Drawdown 10 feet; see analysis.
27	Lawrence School	1½ miles N. of Easton	211	6	Conococheague limestone		20	
28	South Easton Water Co.	1½ miles NW. of Easton	450	10	do	3	500	Suction pump indicates moderate drawdown; water enters at 5 horizons.
30	Easton Sanitary Milk Co.	Easton	259	6	do	20	100	Suction pump; 60 feet of casing.
31	Moyer Dairy Co.	do	91	6	do		50	See analysis.
32	Easton Merchants Ice Co.	do	150	6	do		150	
33a	Dexter Portland Cement	Nazareth	570	8	Jacksonburg limestone	85	150	Drawdown 70 feet.
33b	do	do	606	8	do	80	150	Drawdown 70 feet.
34	Robert Felker	Seidersville	208	6	Hardyston quartzite	90	15	Water enters at 190 feet.
35	H. S. Snyder	Green Pond	350	6	Conococheague limestone		dry	
36	do	do	125	6	do		50	100 feet of casing; near sink hole filled with water; see analysis.
37	Northampton Country Club	1 mile E. of Farmersville	260	10	do	117	125	Drawdown 7 feet.
38	John Rau	1½ miles E. of Farmersville	162	6	do		50	
39	Robert Person	½ mile N. of Farmersville	191	6	do	70	20±	Water enters at 185 feet.
40	Wilson Arbogast	Farmersville	265	6	do	45	20	Water enters at 140 and 220 feet.
41	Aaron Mosser	½ mile N. of Butztown	110	6	do	35	15	Water enters at 70 and 100 feet.
42a	City of Bethlehem	1 mile N. of Bethlehem	1,012	8	do		1,450	Flows 150 gallons a minute; see analysis.
42b	do	do	700	8	do		800	
42c	do	do	750	8	do		800	
43	do	Bethlehem	300	6	do		312	Abandoned.
45	Bethlehem Silk Co.	Bethlehem	400	10	Conococheague limestone	10	900	Drawdown less than 15 feet.
46	Gorman Brothers	do	100	6	do	50	35	
47	William Weaver	Freemansburg	125	6	do	60	15	Water enters at 115 feet.
48	Myer Herberger Dairy	Bethlehem	171	10	do	45	150	Drawdown 10 feet.
49	John West	¾ mile SE. of Middletown	139	6	do	90	50	
50	do	do	235	10	do		200	

51a	South Easton Water Co.	South Easton	80		do			Nos. 51a and 51b have combined yield of 850 gallons a minute.
51b	do	do	350		do			
52a	Emma Lerch	½ mile SE. of Redington	262	6	Tomstown limestone		dry	
52b	do	do	180	6	do		20	
53	Lehigh V. Cold Storage Co.	South Bethlehem	425	10	do		200	Drawdown 35 feet.
54	Lehigh Steam Laundry	do	189	6	do		100	100 feet of casing.
55	South Bethlehem Brewing Co.	do	163	8	do	54	100	
56	Bethlehem Steel Co.	do	773	8	do		200	Air lift.
57	do	Coke plant, Bethlehem	353	10	do		700	
58	do	do	150	16	do		500	Only 10 feet from No. 57.
59a	do	do			do			Two wells 300 feet from Nos. 57 and 58 and similar to them.
59b	do	do			do			
60	John Weaver	North Hellertown	150	8	do	45	100	Loose material, possibly glacial drift.
61	Park Hotel	Hellertown	106	6	Conococheague limestone		300	Flows; water enters at 106 feet.
62	Ted Meyers	½ miles W. of Shimers	117	6	Tomstown limestone		25	
63a	D. G. Dery Silk Mfg. Co.	Northampton	500		Beekmantown limestone		dry	
63b	do	do	119	6	do		50	Water enters at 115 feet
64	Northampton Brewing Co.	do	240	4	do		100	Water enters at 50 and 60 feet.
65	George Holton	1 mile NE. of Catasauqua	225	6	do	55	10	Water enters at 190 feet.
66a	Borough of Siegfried	1¼ miles N. of Siegfried	300	8	Jacksonburg limestone		100	
66b	do	do	200	8	do			Nos. 66b and 66c have combined yield of 45 gallons a minute
66c	do	do	200	8	do			
67	Borough of Bath	Bath	700	8	Martinsburg shale		50	Flows 50 gallons a minute; pumps 150 gallons a minute; drawdown 150 feet. 10 inch at top.

PHILADELPHIA COUNTY

GENERAL CONDITIONS

Philadelphia, which is coextensive with Philadelphia County, has an area of 128 square miles, and has a population, according to the United States Census of 1930, of 1,950,961. It ranks third among the cities of the United States, and is one of the most important manufacturing and commercial centers of the country.

With the exception of a small area in Overbrook, which uses ground water, the entire city is supplied from surface water obtained from the Delaware and Schuylkill rivers, and the demand for ground water for domestic use is small. In the northeastern part of the county, however, where conditions are rural rather than urban, many isolated dwellings still use wells. Some industrial plants which require large volumes of water find that the cost of city water is an item in their manufacturing costs, and, where possible, have obtained ground-water supplies. Ground water is particularly desirable where water is used for cooling because it has a uniform temperature of 50°-55° F. throughout the year, while waters obtained from surface sources range from 39° F. in winter to 65° F., or more, in summer. The lower temperature of ground water during the summer months makes it valuable for cooling. Where obtainable in sufficient quantity, it is also valuable for boiler water unless highly mineralized.

GEOLOGY OF PHILADELPHIA COUNTY

The geology[1] and the water resources[2] have been described in publications of the United States Geological Survey. The oldest formation outcropping in the county is the Baltimore gneiss with which are associated other pre-Cambrian schists and gneisses as well as igneous intrusives. In Mesozoic and Tertiary times sediments of the Atlantic Coastal Plain were deposited on the eroded crystalline rocks. Subsequent earth movements and erosion have removed part of these still unconsolidated sands and clay so that today only part of the city—chiefly along the Delaware and Schuylkill rivers—is now underlain by them. It is unfortunate that these sediments which furnish large supplies of ground water are not more extensive because many industrial plants have been unable to obtain water from the pre-Cambrian crystalline rocks. Several terraces exist along the rivers which record successive uplifts of the region since Quaternary time but they are unimportant as sources of ground water.

[1] Bascom, F., and others, U. S. Geol. Survey Geologic Atlas, Philadelphia, Pa.-N. J.-Del. folio (No. 162), 1909.

[2] Bascom, F., Water resources of the Philadelphia district: U. S. Geol. Survey Water-Supply Paper 106, 1904.

Geologic column in Philadelphia County

Age	Name and description	Thickness	Water-bearing properties
	SEDIMENTARY ROCKS		
Quaternary	Talbot formation. Sand, clay, and gravel.	0–20	Too thin to be important as source of water.
	Wicomico formation. Sand, clay, and gravel.	0–20	Too thin and well drained to contain much water.
Tertiary (?) (Pliocene?)	Bryn Mawr gravel.	0–25	Unimportant as a source of water
Upper Cretaceous	Raritan formation. Light-colored sand and clay, with some iron stone.	0–200(?)	Sand and gravel yields large volumes of water; clays are impervious.
	Patapsco formation. Sand and clay.	40	
Ordovician and Cambrian	Gray, blue and dove limestone.	?	Water occurs in solution channels.
Lower Cambrian	Chickies quartzite. Sandstone, conglomerate, and quartzite.	?	Wells yield from 5 to 100 gallons a minute. Water usually very good.
Pre-Cambrian	Wissahickon formation. Mica schist and gneiss.	?	Average yield 5-10 gallons a minute. Some wells yield up to 100 gallons a minute.
	Baltimore gneiss. Banded gneiss composed of quartz, feldspar, and mica.	?	Not a prolific source of water. Yield of average well 1 to 5 gallons a minute.
	IGNEOUS ROCKS		
Pre-Cambrian	Serpentine. Mostly serpentine and talc, with some metapyroxenite and metaperidotite.	?	Fair water horizon. Water may be highly mineralized.
	Gabbro. Dense, medium-grained rock composed of feldspar, hypersthene and augite.	?	Poor water horizon. Wells yield small supplies. Some wells are failures.
	Granite gneiss. Composed of quartz, orthoclase, biotite, and hornblende.	?	Fair water horizon.

The Baltimore gneiss is overlain by the Wissahickon formation, which takes its name from Wissahickon Creek, a tributary of the Schuylkill River. The exposures of this formation along Wissahickon Creek in Fairmount Park are magnificent. The creek flows through a relatively narrow gorge and erosion is sufficiently active to afford excellent outcrops of the formation which, in its type locality, is a mica gneiss. Although this formation is ordinarily a medium to coarse-grained, banded gneiss or schist characterized by an excess of mica, in the Philadelphia area it develops at least three well marked phases. The rock in the vicinity of Chestnut Hill is composed of beds which are alternately micaceous and quartzose. Cleavage and jointing are well developed. In the vicinity of Manayunk the Wissahickon formation is intruded by a large body of granite gneiss. Farther south it consists of mica gneiss with an abundance of andalusite and sillimanite. The water-bearing properties of this formation are of great importance in Philadelphia, because it is the formation which lies either immediately beneath the surface or at a depth of less than 300 feet beneath the coastal plain sediments. In many places wells yield very small supplies while in other places some wells yield as much as 100 gallons a minute.

Upon the eroded edges of the pre-Cambrian rocks were deposited the gravels, sands, and clays of the Patapsco and Raritan formations

of Lower Cretaceous age. Although a long period of time has elapsed since these sediments were laid down, they have not been consolidated into solid rock except locally where some of the sands are indurated and form a very friable sandstone. At the mouth of Schuylkill River they are apparently thicker than in the adjoining areas.

The sands and gravels are excellent aquifers, but the clays are practically impervious. The sands and gravels are frequently lenticular and consequently wells which are but a few hundred feet apart have very different yields. Water-bearing sands give way to tight clays and an occasional well may be drilled almost entirely in clay with the result that it yields little or no water. Such instances of complete failure are rare, however.

The Cretaceous deposits are covered with terrace deposits and alluvium in the Philadelphia area. These terraces were once well marked along the rivers, but the grading of city streets has largely obliterated the more conspicuous evidences of their existence. In most places the terrace deposits and the alluvium are very thin and rarely exceed a few feet in thickness. Apparently the alluvium has never been important as a source of ground water and due to its disturbance and partial removal by man is now even of less importance.

Philadelphia County is not divided into townships but into wards, and a discussion of the ground-water conditions under such small divisions would be tedious.

In general, the wells northwest of a line connecting Point Gibson on Schuylkill River and Point-no-Point on Delaware River encounter the crystalline rocks at a relatively short distance below the surface. Consequently, these wells draw the bulk of their water from the crystalline rocks. South of that line the contact of the crystalline rocks and the unconsolidated sediments slopes southeastward. Consequently, as one goes farther southeastward from this line the deeper the wells must be to reach this favorable horizon at the contact of the two formations. The greatest reported depth at which the crystalline rock was encountered is 270 feet in a well at the Navy Yard on League Island. In this area most wells obtain their water either from sandy layers in the Raritan formation or in the basal sand at the contact of that formation with the crystalline rock.

A number of wells (Nos. 1 to 7) have been drilled in the Wissahickon formation in the Frankford area. These wells show that the Wissahickon formation and the associated crystalline rocks yield fair supplies of water, but in general one can not expect to obtain large supplies. The northeastern portion of Philadelphia County is probably as thinly inhabited as any part of the county, and a number of homes are isolated from the city water so that they are dependent upon wells and springs. New houses should not be erected until a well has been drilled and its capacity determined except where city water is available. In most cases wells can be drilled which will more than supply ordinary household needs.

A number of wells have been drilled in the Wissahickon formation in Germantown and vicinity but most of them are reported to yield small volumes of water.

Although Lansdowne and vicinity have long had public supplies derived from surface waters, a number of wells have been drilled.

There are two wells on the Theodore Presser Estate, one of which has an unusually high yield for a well in crystalline rock (Nos. 10, 11).

Frequent attempts made in Philadelphia to obtain water from the Wissahickon formation have met with varying success. The Potter Linoleum Company has four wells (Nos. 18 to 21), one of which is an exceptionally good well yielding 150 gallons a minute. The well (No. 22) at the Aquarium, in Fairmount Park, was drilled to supply the Aquarium with cold water in summer time for those fish which require water at a temperature below that of the city supply. About 100 gallons a minute were needed and the well was drilled to 496 feet without obtaining the desired amount. The American Ice Company has two wells that are only a few yards apart and are excellent illustrations of the peculiarities of the occurrence of ground water in crystalline rocks (Nos. 23, 24). The well of the Curtis Publishing Company (No. 25) yields a large volume of water for a well drilled in the Wissahickon formation. In places, considerable quantities of water are available from the crystalline rocks (Nos. 1 to 34). However, the yield of any one well is very uncertain and wells but a few feet apart may yield very different quantities of water. The writer feels that a number of failures to obtain water have occurred but drillers are reluctant to talk about unsuccessful wells. Consequently, data on failures are difficult to obtain.

The largest supplies of ground water are obtained from the coastal plain formations in the southern part of the city. The contact of these beds and the underlying crystalline rock extends in an easterly direction from Schuylkill River, crosses Broad Street about 1 mile north of the City Hall, and then swings northeastward more or less parallel to Delaware River. These beds, in general, strike northeast-southwest and dip about 40 feet per mile to the southeast. At the contact, these beds are too thin to be of any importance as a source of water but as they thicken to the southeastward the sands and gravels contain large volumes of water. The shallowest wells in the coastal plain deposits are four 2-inch drilled wells of the Pennsylvania Cold Storage and Warehouse Company (Nos. 35 to 38).

The unconsolidated sediments of the Coastal Plain are, in the southern part of Philadelphia, an excellent source of ground water and wells of large diameter yield large volumes of water (Nos. 55 to 58). The most important use of this water is for cooling and in some cases for boiler feed. It is doubtful whether it can be used for drinking because it is very probable that it may be contaminated. Apparently the largest volume of water is available at the contact of the unconsolidated sediments and the crystalline rocks. The latter form an almost impervious base and consequently water accumulating in the unconsolidated sediments seeps downward until it encounters the almost impervious base where it collects in large quantities.

No data are available concerning any change in level due to heavy draft upon the aquifer. The area of recharge must be, in part, the exposed edges of the formation which, in Philadelphia, are more or less covered with buildings and streets. These structures must deflect some of the water from percolating into the ground and divert it into the run-off. Probably the major portion of the water is derived from the small streams which cross the contact. However, many of the smaller streams have been converted into storm-water drains with im-

pervious walls. Consequently, the Philadelphia area could be made the subject of a profitable quantitative ground-water study to determine the effect of human activities on the recharge of the aquifer. As the draft on this valuable horizon increases all users should keep a careful check on the lowering of the water level in the wells and any decrease in yield.

Some wells have been reported which did not find water-bearing materials at or near the contact with the crystalline rocks, but encountered lenses of almost impervious clay. In some cases it was decided to deepen these wells and to seek supplies in the solid rock. While some of the attempts have proven successful, the practice is not to be recommended. None of these wells are reported to yield supplies over 100 gallons a minute, and many of them are almost total failures.

DRILLED WELLS IN PHILADELPHIA COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gal. min.	
1	Philadelphia Sashweight Works	22d & Glenwood Ave Frankfort	126	8	Wissahickon formation		45	
2	Blumenthal Bros.	Margaret & James Sts.,	511	8	do	15	36	
3	do	do	244	8	do		8	19 feet 3 inches of casing
4	S. D. Milner	do	133	6	do	28	12	Water enters near bottom
5	Baldwin Milk Dairies, Inc.	do	900	6	do		5	Water enters in first 100 feet
6	Jacob Bentz	Torresdale	70	6	do	17	3	
	Fish Hatchery	do	143	8	do	16	90	
7	Philadelphia Board of Education	Academy & Byberry Road, Philadelphia	90	6	do	17	27	
8	Harbison Milk Dairies, Inc.	Kensington Av. & Nicetown	525	8	do		150	Mica rock and granite
		Lane, Philadelphia	525	8	do		70	
9	Lansdowne Ice & Coal Co.	Philadelphia	250	6	do		20	
10	Theodore Pressor Estate, Lansdowne	do	525	6	do		150	
11	do	do	300	6	do		60	
12	A. C. Stevens	3500 Lancaster Av.	201	6	do		3	
13	Mrs. William S. Chester	69th & Chester Av.	40	6	do		5	Put in for drainage
14	do	do	40	6	do		5	
15	do	do	123	6	do		5	
16	do	do	52	6	do		5	
17	do	do	60	6	do		5	
18	Potter Linoleum Co.	Erie Av., 2d & 3d Sts.	900	8	do		10	Mica gneiss. All drilled in area of 2 acres
19	do	do	500	8	do		10	
20	do	do	500	8	do		10	
21	do	do	350	8	do		150	
22	Aquarium Fairmount Park	Philadelphia	496	6	do	10	28	Water enters at 198 feet
23	American Ice Co.	America & Cambria Sts.	100	8	do		60	
24	do	do	150	8	do		30	
25	Curtis Publishing Co.	7th & Walnut Sts. do	500	8	do		150	Not good for boilers.
26	Horn & Hardart Baking Co.	10th near Walnut St. do	400	6	do		75	
27	Racquet Club	16th near Sampson St. do	500	6	do		500	Two wells
28	Hamilton Court Apartment	39th & Chestnut Sts. do	450	6	do		70	
29	S. B. & B. W. Fleisher	26th & Race Sts. do	500	8	do		100	Mica rock 25′ to bottom
30	Supplee-Wills-Jones Milk Co.	26th & Jefferson Sts. do	200	8	do		7	24 feet of casing
31	do	do	300	8	do		45	24 feet of casing
32	do	do	200	8	do		17	24 feet of casing
33	do	do	200	8	do		3	24 feet of casing

No.	Owner	Location	Depth	Diameter	Water-bearing formation	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gal. min.	
34	Quaker City Dairy Co.	236 Greenwich St. do	109	8	Wissahickon formation	10	100	
35	Pennsylvania Cold Storage & Warehouse Co.	Delaware Av. & Spruce St. Philadelphia	35	2	Patapsco formation		30	
36	do	do	35	2	do		30	
37	do	do	36	2	do		30	
38	do	do	33	2	do		30	
39	Harry Sheltzline	27th & Pattison Av. do	73	6	do	27	100	
40	Publicker-Ward Distilling Co.	Philadelphia	72	8	do	6	150	
41	do	do	73	8	do	10	120	
42	J. F. Johnson & Co.	509 S. 10th St., Phila.	84	10	do	29	100	
43	Lifter Ice Cream Co.	2d & Lombard Sts., do	90	10	do		150	
44	do	do	94	10	do		100	
45	Crescent Ice & Coal Co.	25th & Morris Sts. do	90	8	do		50	Furnished with 20-foot slotted pipe
46	American Feeding & Products Co.	Delaware Av. & Snyder St.	117	6	do	17	120	
47	W. J. McCahn Sugar Ref. Co.	S. Delaware Av. do	117	8	do		190	Well ends in gravel; abandoned
48	Philadelphia Ship Repairing Co.	Philadelphia	130	6	do	9	80	
49	Baugh & Sons Co.	Morris St. & Delaware Ave.	133	8	do	9	200	Suction pump
50	David Berg Distilling Co.	Delaware Av. & Morris St.	250	8	do		500	12-inch at top; 150 feet to rock, 4 or 5 other wells
51	Indian Refining Co.	McKain & Swanson Sts.,	150	8	do		200	
52	Morgenthaler Bros.	2d & Snyder Av., Phila.	169	10	do		300	Rock at 160 feet
53	do	do	168	10	do		275	Rock at 160 feet
54	American Com. Alcohol Co. No. 2	Front St. & Snyder Av.,	153	12	do		300	Cooling water
55	do No. 1	do	168	16	do (?)		400	do
56	do No. 3	Delaware Av. & Biegler St.	175	16	do		400	do
57	Harshaw Chemical Co.	Swanson & Jackson Sts.	196	16	do		800	Water from two horizons
58	do	do	196	12	do		550	do

YORK COUNTY

GENERAL CONDITIONS

York County is situated in the south-central part of the area under discussion, and is separated from Maryland by the Mason and Dixon line, and from Lancaster County by Susquehanna River. It is bounded on the north and west by Cumberland and Adams counties. The area of York County is 903 square miles, and the population, according to the United States Census of 1930, was 167,135, or 185.1 inhabitants per square mile. The density is about 85 per cent of that for the entire State. The rural population is more than 50 per cent of the total. The number of farms is 7,647. The city of York, which is the county seat and has a population of 55,254, is supplied with surface water from Codorus Creek, but the rural population and a considerable number of urban dwellers are dependent on ground-water supplies.

GEOLOGY OF YORK COUNTY

York County, like most other counties, includes the three belts of rocks in which the rocks of southeastern Pennsylvania can be grouped. The southeastern part of the county consists of late pre-Cambrian (Algonkian) rocks, including (in ascending order) Cockeysville marble, Wissahickon formation, Peters Creek schist, Cardiff conglomerate, and Peach Bottom slate. The valley, which extends from the Susquehanna River to the Maryland line, in which are situated York and Hanover, is underlain by limestones of Cambrian and Ordovician age. In the northern part the county is underlain by Triassic sediments with intrusions of diabase. In places erosion has removed these beds and exposed the underlying limestones. North of the limestone valley the Lower Cambrian schist and quartzite and pre-Cambrian rocks form low but conspicuous hills.

For the convenience of the users of this section of the report a geologic column is inserted. The data for this column were obtained from the following publications:

Jonas, A. I., and Stose, G. W., Topographic and Geologic Atlas of Pennsylvania, Lancaster Quadrangle, No. 168, p. 14, (Fig. 2), 1930.

Knopf, E. B. and Jonas, A. I., Geology of the McCalls Ferry-Quarryville District, Pennsylvania: U. S. Geol. Survey Bull. 799, p. 16, (Fig. 3), 1929.

Stose, G. W. and Bascom, F., U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (No. 225), p. 22, 1929.

Stose, G. W. and Jonas, A. I., Geology of the Middletown quadrangle, Pennsylvania: U. S. Geol. Survey Bull. 840, Pl. 3, 1933.

Geologic column for York County

Age	Name and description	Thickness	Water-bearing properties
	SEDIMENTARY ROCKS	Feet	
Upper Triassie	Gettysburg shale. Chiefly soft red shale and sandstone witb some conglomerate. Metamorphosed where intruded by diabase. Fanglomerate at top, of quartz pebbles set in a matrix of argillaceous Sand-stone.	4,500	A fairly good water-bearing horizon. Few wells are failures; most wells yield adequate domestie supplies; and a few wells yield 100 or more gallons per minute. Ground water occurs in the bedding, joint, and fracture planes of tbe shales and in the more pervious sandstones.
	New Oxford formation. Light-gray to grayish-yellow, arkosic sandstone with interbedded red shale. Some quartz pebble conglomerate near base.	4,500	A good water-bearing horizon. Wells may yield as much as 200 gpm.
	Unconformity		
Ordovician (Lower ? Ord.)	Conestoga limestone. Thin-bedded, blue limestone and gray granular limestone with limestone conglomerate at base.	1,000±	
	Unconformity		
Lower Ordovician	Beekmantown limestone. Pure, light-gray limestone, magnesian limestone and gray dolomite with quartz and calcite veins. Contains black chert.	2,000±	The yield of wells is dependent upon the volume of water which is available in solution channels encountered in drilling.
Upper Cambrian	Couococheague limestone. Light-blue limestone banded with siliceous impurities, dolomite and fine-grain marble.	1,0[illegible]	Most wells yield sufficient water for domestic purposes but some "dry holes" are reported. The calcareous shales are less favorable water-bearing formations than limestone.
Upper and Middle Cambrian	Elbrook limestone. Tbin-bedded to shaly, fine-grained, white to cream-colored marble and limestone with sericitic partings.	1,000	
Lower Cambrian	Ledger dolomite. Light-gray, pure, granular dolomite with some chert.	1,000±	
	Kinzers formation. Dark shale below, blue banded limestone aud spotted marble above.	200	
	Vintage dolomite. Dark-blue, knotty dolomite with impure marble at base.	600±	
	Antietam quartzite. Gray quartzite with granular ferruginous quartzite at top.	400±	Fairly good water-bearing horizon. Springs yield excellent water.
	Harpers schist. Light-gray phyllite and schist, and dark banded slate.	1,000±	Not a good water-bearing formatiou, but most wells in it yield small supplies.
	Chickies quartzite. Massive white quartzite and quartz schist with sericitic partings. Hellam conglomerate member at base. Glassy quartz pebble conglomerate.	700±	Yields small supplies of excellent water.
	Unconformity		
Algonkian (Glenarm series)	Peach Bottom slate. Dark bluish-gray slate.	1,000±	Unimportant as a ground-water horizon. Few wells have been drilled in either formation.
	Cardiff conglomerate. Quartz pebbles in a schistose matrix of quartz, sericite, and cblorite.	?	
	Peters Creek schist. Cbloritic and sericitic quartz scblsts interbedded with chlorite-sericite schists.	?	A fairly good water-bearing formation. Most wells in this schist yield small supplies of water.

Age	Name and description	Thickness	Water-bearing properties
		Feet	
Algonkian	Wissahickon formation. Albite-chlorite schist facies.	?	A fairly good water-bearing formation. Few wells are failures and some yield 100 or more gpm.
	Cockeysville marble.	?	Unimportant as a source of ground water.
	IGNEOUS ROCKS		
Triassic	Diabase. Dikes and sills of fine to medium-grain igneous rock.	?	A poor ground-water horizon.
Algonkian	Metabasalt. Massive greenstone	?	A poor ground-water horizon. Few wells have been drilled in this rock. Some springs issue from it in Pigeon Hills.

TOWNSHIP DESCRIPTIONS

Chanceford, Lower Chanceford, Fawn, and Peach Bottom townships. The oldest rocks outcropping in these townships belong to the Cockeysville marble. The water-bearing properties of this formation are probably similar to those described in Chester County on pages 137, 138.

The Cardiff conglomerate is overlain by the Peach Bottom slate. The slate is found in a ridge which is formed by the conglomerate. The slate quarries all have trouble with water, but the influx is small per unit area. The borough of Delta obtains its water from a well 180 feet deep which is probably in the slate. Few wells have been drilled in the slate because the needs of the population have not required large volumes of water.

Hellam, Windsor, Lower Windsor, Hopewell, North and East Hopewell townships. The oldest formation outcropping in these townships is the Wissahickon formation, which is at the surface over all but the northern part of this area. The Wissahickon formation yields small supplies to both dug and drilled wells. In this region springs and dug wells have been the main source of supply in past years, but the wells at newly erected dwellings are usually drilled. The borough of Stewartstown obtains its supply from a drilled well in the schist.

The Wissahickon formation is overlain by Chickies quartzite, with its prominent Hellam conglomerate member, north of the borough of Hellam. The irregular, low, rugged hills in Hellam Township north of the limestone are made of the conglomerate. This area is thinly settled and springs and dug wells adequately supply present needs. The borough of Hellam utilizes a group of several springs which issue from the Hellam conglomerate near the headwaters of Kreutz Creek. The water flows to the borough and is distributed by gravity.

The Chickies quartzite is overlain by the Harpers schist and the Antietam sandstone or quartzite. These formations outcrop on the north and south sides of the valley and form low, rounded hills. Few wells have been drilled in these rocks and little definite information concerning their water-bearing properties is available. However, drilled wells should yield small supplies adequate for domestic use. The Antietam quartzite is overlain by limestones of Cambrian and Ordovician age. These limestones, on account of their being less resistant to erosion, form a narrow valley between the older and more

resistant formations. The occurrence of ground water in limestones has been discussed in a previous chapter. People living along the north and south sides of the valley should develop the soft water springs in the hills and pipe them to their homes. The difference in elevation is usually sufficient to develop enough pressure to furnish running water in both the home and out building. By developing gravity supplies the cost of pumping is eliminated.

The borough of Wrightsville, the largest in the area, obtains its water from Kreutz Creek.

East Manchester, Springetsbury, Spring Garden, York, Springfield, and Shrewsbury townships. The Wissahickon formation is at the surface over much of Springfield and Shrewsbury townships. In most places springs and dug wells are the main source of supply. The borough of Glen Rock obtains water from the south branch of Codorus Creek. The borough of Railroad, in Shrewsbury Township, is supplied by a group of springs east of the town. The water flows to the borough and is distributed by gravity. The borough of Shrewsbury is supplied by springs and wells. The borough of New Freedom obtains its supply from two 8-inch drilled wells. One is 127 feet deep, and the other is 102 feet deep. Their combined yield is less than 100 gallons a minute. Although the yield of springs and wells is usually small, by combining the yield of several springs or wells or both, supplies of considerable size can be developed.

The Wissahickon formation is overlain by the Chickies quartzite, the Harpers schist, and the Antietam sandstone. The Chickies quartzite with its basal Hellam conglomerate member is best exposed in a few areas in East Manchester Township. The Harpers schist and the Antietam sandstone are well exposed both north and south of the York Valley. A small spring on the Baltimore Pike, near the York Water Company's reservoir, flows 2 gallons a minute (See analysis No. 1). The water in Codorous Creek closely resembles, in quality, the water from the spring mentioned. Codorus Creek above the York Water Company's dam, flows over the Wissahickon formation, the Harpers schist, and the Antietam sandstone. Drilled wells are less numerous than dug wells and many people depend upon springs. The boroughs of Dallastown, Yoe, and Windsor are supplied by a group of springs .5 mile east of Dallastown, which forms the source of a tributary of Mill Creek. Red Lion obtains its water from four groups of springs and a number of wells in the vicinity of the borough. Springs are valuable sources of ground water, and with proper development, yield considerable volumes of water.

The Antietam sandstone is overlain by the Cambrian and Ordovician limestones, which by their more rapid erosion form the depression known as the York Valley. The occurrence of ground water in limestone has been discussed in a previous chapter. A number of wells have obtained yields of 100 gallons a minute or more in and around York, but other wells are reported as failures. Deep drilling in the York area is usually unsuccessful, and wells dry at 250 or 300 feet should be abandoned. The chances of obtaining water are more favorable at a new site than in drilling deeper at the old site because water-bearing openings become less numerous in depth. Water from the limestone is hard, but on account of its low temperature, is valuable

for cooling. On account of the hardness of the water many people supplement the ground-water supplies with rain water stored in cisterns.

Fairview, Newberry, Conewago, Dover, Manchester, and West Manchester townships. In these townships the Chickies quartzite, with its basal Hellam conglomerate member, is of little importance as a source of ground water on account of its small area of outcrop. The Chickies quartzite is overlain by the Harpers schist and the Antietam sandstone in the order named. Small springs issuing from these formations are used by many people. The town of Emigsville is supplied by a group of springs issuing from these rocks. Drilled wells should yield adequate domestic supplies at moderate depths. The limestones of Cambrian and Ordovician age are exposed in the southern part of the area in Manchester and Newberry townships, and in the northern part in Fairview Township. Some wells which were drilled in the shaly parts of the Lower Cambrian dolomites yield very little water. The limestones usually yield to wells from 50 to 250 feet deep small supplies adequate for domestic use, but an occasional well may yield a large supply while other wells are failures (Nos. 4 and 5). The yield is dependent on the well striking water-bearing solution channels.

The limestones are overlain unconformably by sediments of Triassic age which consist primarily of sandstone and shale. The major portion of Fairview, Newberry, and Dover townships is underlain by these sediments, the predominating color of which is red and which weather to a characteristic red soil. The Triassic rocks usually yield small domestic supplies at depths ranging from 50 to 250 feet (Nos. 3 and 6). In places supplies up to 100 gallons a minute can doubtless be obtained. The arkosic sandstones should yield larger supplies than the shales.

Intrusions of diabase are numerous and conspicuous in the area included in this group of townships. The intrusions are usually in the form of dikes which cut through the sediments without regard to their strike or dip. Due to greater resistance to erosion these rocks usually form ridges. A spring in Pythian Park, York Haven, flows about half a gallon a minute. The waters obtained from the diabase show considerable variation in dissolved mineral content. Unless water is encountered in the first 75 or 100 feet in the diabase it is unwise to drill deeper because fresh diabase is quite impervious. The best place to obtain water in the dikes is in the vicinity of the contact of disintegrated and solid diabase (No. 8).

North Codorus, Codorus, Manheim, and West Manheim townships. The oldest formation in these townships is the Cockeysville marble. The marble crops out in a long narrow valley in Manheim and Codorus townships. The marble is overlain by the Wissahickon formation, the Lower Cambrian formations, and the limestones of Cambrian and Ordovician age. The water-bearing properties of these formations are discussed under other townships. Little information about wells is available in the area.

Monaghan, Carroll, Franklin, Warrington, and Washington townships. The oldest rocks exposed in these townships are the pre-Cambrian volcanic rocks in South Mountain. These altered lavas

are unimportant as sources of ground water in this area. Overlying these ancient rocks unconformably are Triassic sedimentary beds. In places, as in the vicinity of Dillsburg, the Triassic rocks have been eroded and the underlying Cambrian and Ordovician limestones have been exposed. The water-bearing properties of these limestones are the same as in the other parts of the county, except the diabase intrusions have further complicated the circulation of ground waters in their vicinity. The Triassic sediments consist of interbedded sandstone and shale, arkose, and conglomerate. The rocks change rapidly, both vertically and horizontally, shale replacing sandstone and vice versa. For wells in these rocks see Nos. 10 and 11.

The Triassic sedimentary rocks contain intrusions of diabase. Diabase dikes are numerous in the vicinity of Dillsburg. In general the diabase yields small supplies at relatively shallow depths. It is unwise to drill far into diabase because it is hard and tough as well as almost impervious.

Paradise, Jackson, Heidelberg, and Penn townships. The pre-Cambrian volcanic rocks are exposed in Pigeon Hills. Springs issuing from these rocks and the overlying Cambrian sediments furnish part of the water supply for the borough of Hanover. The remainder of the supply is from surface water. The volcanic rocks are overlain by the Chickies quartzite, the Harpers schist, and the Antietam sandstone. These rocks occur not only in the Pigeon Hills but also in a broad belt of rolling hills between Hellam and York Haven. They can be depended upon to yield small supplies of very good water. The Antietam sandstone is overlain by limestones of Cambrian and Ordovician age. Wells in these rocks are typical of wells ending in limestone. (Nos. 12 to 15).

The Triassic sediments rest unconformably on pre-Cambrian, Cambrian, and Ordovician rocks. They consist chiefly of sandstones and shale with subordinate amounts of arkose and conglomerate. Wells in these show that in general adequate domestic supplies can be obtained. (Nos. 18 to 20). The wells at St. Mary's church near Abbottstown indicate that occasional wells may be failures. (Nos. 16 and 17).

DRILLED WELLS IN YORK COUNTY

No.	Owner	Location	Depth	Diameter	Water-bearing formations	Depth to water level	Yield	Remarks
			Feet	Inches		Feet	Gals. min.	
2		New Market	50–100	6	Martinsburg shale		5–10	8 wells.
3	V. Potchelber	Yocumtown	120	6	Gettysburg shale	35	10	Water enters near bottom.
4	Sandusky Cement Co.	West York	300	8	Ledger dolomite		100	
5	H. E. Crist	1½ miles E. of Thomasville	48	6	do		3	See analysis.
6	Robert Prowell	1½ miles NW. of Yocumtown	56	6	Gettysburg shale	20	5	do
7	City Dairy Co.	do	150	6	do		100	
8	Prowell's Grove	1¼ miles NW. of Yocumtown	50	6	Diabase		3	Another similar well 60 feet deep; see analysis.
10	Hershey Creamery Co.	Dillsburg	200	6	Gettysburg shale		50	
11	do	do	300	6	do		10	Only 200 feet from No. 10.
12	Hanover Ice Co.	Hanover	415	8	Conestoga limestone		100	
13	Hokes Creamery	do	500	10	do		150	
14	Electric Light Plant	do	550	10	do		1	Solid rock almost dry.
15	Fulmer Ice Plant	do	540	8	do		25	
16	St. Mary's Church	1½ miles NE. of Abbottstown	1,005		New Oxford formation			Abandoned; water has an oily taste; small yield.
17	do	do	240		do			Abandoned; small yield.
18	John Dalheimer	3 miles NE. of Abbottstown	10	36	do	2–8	Several	Dug well.
19	do	do	22	36	do		do	See analysis.
20	Mr. Storm	1½ miles E. of Abbottstown	174	6	do		12	

Analyses of waters from southeastern Pennsylvania

(Parts per million. Numbers correspond to numbers in tables of well data for the counties)

ADAMS COUNTY

No.	Source, location, depth, formation	Date of collection, 1925	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
3	York Sulphur Spring, 1 mile SE. of York Springs, Triassic	Oct. 31	1,106	22	.07	209	8.3	[b]103		148	581	41	Trace	557	50	H
8	Well 3 miles N. of Hanover, 18 feet, Beekmantown (?) limestone	Nov. 1	566	24	.08	100	40	[b]42		326	67	114	10	414	54	H
14	Well 1½ miles E. of New Oxford, 55 feet, Triassic	Nov. 1	411	8.4	.08	97	19	[b]15		248	37	30	84	320	52	H
17	Well 1½ miles W. of New Oxford, 20 feet, Triassic	Nov. 1	72	6.2	22	8.2	4.7	4.1	.6	16	22	5.8	5.7	40	54	H
18	Well 1½ miles W. of New Oxford, 20 feet, Triassic	Nov. 1	288	16	.14	47	11	[b]24		105	73	22	27	163	54	H
25	Well in Gettysburg, 400 feet, Triassic	Oct. 30	377	24	.08	73	19	[b]14		190	82	27	14	260	54	H
28	Well 1¾ miles NW. of Gettysburg, 80 feet, Triassic	Oct. 30	371	16	.14	76	27	14		277	25	57	1.2	301	52	H
34	Well 3½ miles NW. of Gettysburg, 36 feet, diabase	Oct. 29	333	36	.17	53	27	[b]1.7		155	59	13	50	243	54	H
35	Well 6 miles NW. of Orrtanna, 76 feet, Pre-Cambrian	Oct. 28	52	15	.17	3.9	1.8	5.3	.8	28	3.6	1.0	Trace	17	-------	H
37	Spring 3½ miles NW. of Orrtanna, owned by G. A. King, Pre-Cambrian	Oct. 27	50	17	.08	4.9	2.2	2.8	1.4	16	4.6	2.1	6.6	21	52	H
38	Spring in Cashtown, owned by State of Pennsylvania, Pre-Cambrian	Oct. 30	84	14	.06	9.5	2.7	7.7	1.7	34	8.2	2.6	14	35	51	H
39	Stillhouse Spring, State Forest Reserve, Weverton sandstone	Oct. 28	17	4.8	.08	3.2	.7	.7	.8	7.3	3.9	1.0	Trace	11	50	H

BERKS COUNTY

32	Spring owned by Reading Country Club, Philadelphia road, limestone	Sept.	26	225	14	.08	52	17	4.3	1.9	208	15	5.4	19	200	52	F
37	Spring 5 miles E. of Morgantown, owned by Stephen Stoltzfus, limestone	Oct.	1	241	15	.09	57	20	3.0	1.4	230	16	3.0	29	224	51	F
41	Well in Plowville, 100 feet, Triassic	Oct.	1	68	11	1.4	3.4	1.4	3.6	.6	54	6.3	.9	2.7	14	-------	F
47	Well in Scarlets Mill, 70 feet, Triassic	Oct.	1	66	22	.19	7.4	2.8	3.5	1.0	32	12	1.0	.10	30	54	F
49	Spring 2 miles N. of Beckersville, owned by D. B. Gates, Triassic	Oct.	1	82	30	.06	8.0	2.3	4.4	.7	29	5.0	1.6	12	29	-------	F
83	Well in Mount Etna, 50 feet, Martinsburg shale	Oct.	2	266	9.2	1.4	16	15	b31		15	26	35	102	102	-------	H

BUCKS COUNTY

1	Well 3 miles N. of Point Pleasant, 200 feet, Lockatong formation (?)	Sept.	29	263	28	.01	46	25	14	2.6	267	17	5.5	12	218	52	F
2	Well in Point Pleasant, 150 feet, Lockatong formation	Sept.	29	1,050	19	.35	154	36	161	12	48	51	540	50	533	52	F
11	Well in Gardenville, 112 feet, Lockatong formation	Sept.	29	339	15	.11	62	31	9.3	1.6	236	49	32	10	282	53	F
17	Well in Dublin, 215 feet, Lockatong formation	Sept.	29	316	18	.06	57	29	16	2.2	250	30	42	1.1	261	54	F
30	Spring 2½ miles W. of New Hope, owned by Richard Mattison, limestone (Ingham's Spring)	Sept.	29	156	12	.02	30	17	2.4	1.1	155	13	2.6	8.1	145	52	F
31	Well in Yardley, 210 feet, Stockton formation	Sept.	29	239	21	.07	30	13	28	4.0	90	32	44	25	128	53	F
33-c	Well in Newtown (No. 3) 180± feet, Stockton formation	Sept.	29	130	25	.05	19	7.6	4.8	1.2	69	10	5.5	18	79	54	F
33-d	Well in Newtown (No. 4) 220 feet, Stockton formation	Sept.	29	129	26	.09	19	8.0	4.7	1.6	72	9.7	5.4	17	80	55	F
41	Well in Pineville, 45 feet, Brunswick shale	Sept.	29	497	17	.43	59	35	47	4.8	253	92	65	42	291	54	F
62-a	Springs at Doylestown owned by Doylestown Borough, Stockton formation	Sept.	28	100	28	.07	11	4.5	7.7	1.0	49	9.2	4.2	14	46	-------	F
62-b	Well at Doylestown (No. 1) 187 feet, Stockton formation	Sept.	28	236	34	.10	48	8.6	9.6	1.8	c137	50	6.5	5.4	155	-------	F
96-a	Well 1½ miles N. of Quakertown (No. 1), 367 feet, Brunswick shale	Sept.	30	786	33	.30	152	29	28	4.0	155	401	10	1.4	499	52	F
123	Well 2½ miles S. of Quakertown, 22 feet, diabase	Sept.	30	66	26	.18	5.5	4.4	3.2	.6	37	6.3	3.1	.08	32	57	F

Analyses of waters from southeastern Pennsylvania

(Parts per million. Numbers correspond to numbers in tables of well data for the counties)

CHESTER COUNTY

No.	Source, location, depth, formation	Date of collection, 1925	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
17	Well 1 mile N. of West Chester, 135 feet, Wissahickon formation	Sept. 26	57	14	.21	6.2	2.4	2.8	.9	20	2.7	2.0	13	25	-------	F
18-j	Well at West Chester, 165 feet, gabbro	Sept. 25	82	32	.05	8.4	4.7	3.6	1.2	34	3.0	2.6	16	40	52	F
49	Well at Elverson, 80 feet, Chickies quartzite	Oct. 1	64	7.6	.14	4.6	3.9	6.2	1.4	5.4	4.2	10	25	27	53	F
87	Well at Coatesville, 225 feet, Ledger dolomite	Sept. 25	314	12	.19	72	19	10	1.7	237	41	16	26	158	52	F
93	Well 1 mile W. of Coatesville, 70 feet, Conestoga limestone	Sept. 25	237	10	1.9	58	8.3	1.7	1.6	112	8.3	24	58	179	52	F
98	Well at Ercildoun, 140 feet, Peters Creek formation	Sept. 25	285	8.7	2.7	28	16	38	2.2	34	14	86	64	136	53	F
112	Well at Doe Run Station, 65 feet, Cockeysville marble (?)	Sept. 25	120	17	.04	18	9.8	5.7	1.6	76	11	4.8	21	85	54	F
122	Well at Hamorton, 60 feet, Baltimore gneiss	Sept. 26	354	22	2.0	52	23	15	2.8	45	15	121	50	224	-------	F
126	Well E. of Kennett Square, 84 feet, Baltimore gneiss	Sept. 25	67	31	.31	4.7	2.3	4.3	.9	30	3.7	2.1	1.5	21	-------	F
135	Well at Kennett Square, 69 feet, Cockeysville marble	Sept. 25	271	22	.05	52	29	8.9	1.4	256	13	17	15	249	54	F
147	Well 1 mile SE. of Avondale, 28 feet, gabbro	Sept. 21	96	22	.13	10	4	4.2	1.8	27	8.7	5.3	19	42	-------	F
149-a	Well at Chatham, 28 feet, pegmatite	Sept. 21	324	17	.12	36	19	29	3.0	62	48	52	68	168	-------	F
149-b	Well at Chatham, 125 feet, pegmatite	Sept. 21	851	19	1.0	99	35	112	6.9	20	18	342	167	391	-------	F
153	Well at West Grove, 98 feet, Cockeysville marble	Sept. 21	109	12	.03	15	6.0	6.1	1.8	51	8.8	11	17	62	56	F
163	Well at Parkesburg, 30 feet, Harpers phyllite	Sept. 25	123	6.4	.45	9.0	8.0	12	2.0	6.1	10	16	60	55	56	F
164	Well near Parkesburg, 30 feet, Conestoga limestone	Sept. 25	287	22	.60	78	6.8	1.3	2.4	157	66	12	13	223	52	F
177-b	Well in Cochranville, 151 feet, Peters Creek formation	Sept. 25	261	8.7	.12	24	13	39	3.2	27	15	79	67	113	52	F
189-b	Well at Lincoln University, 184 feet, Wissahickon formation	Sept. 21	74	23	.11	5.4	4.6	3.7	1.6	22	5.0	4.0	16	32	-------	F
190-a	Well at Oxford, 1,004 feet, Wissahickon formation	Sept. 21	68	24	.41	6.0	3.2	4.5	1.8	32	8.9	1.8	.53	28	-------	F

190-(	Well at Oxford, 478 feet, Wissahickon formation	Sept. 21	48	18	.06	3.9	1.9	2.8	1.3	16	4.9	1.9	5.6	18	-------	F
201	Well at Nottingham, 160 feet, Wissahickon formation	Sept. 21	71	36	.22	4.0	2.1	5.6	1.2	29	4.1	1.9	1.0	19	-------	F
208	Well 1 mile N. of Sylmar, 129 feet, serpentine	Sept. 21	131	34	.42	6.6	25	1.6	.9	c129	8.3	2.4	6.3	119	-------	F
211	Well ¾-mile SW. of Nottingham, 100 feet, serpentine	Sept. 21	333	40	.28	2.1	76	4.2	1.0	329	8.5	30	2.7	317	-------	F
213	Spring at Honeybrook, owned by Honeybrook Borough, Hellam conglomerate	Oct. 1	21	5.9	.78	1.6	1.3	1.5	.4	6.1	2.9	2.0	2.0	9.3	-------	F
214	Quarry at Avondale, owned by Avondale Water Co., Cockeysville marble	Sept. 21	171	24	.05	39	6.7	3.2	1.8	134	12	5.7	7.1	125	-------	F
215	Springs in Parkesburg, owned by Parkesburg Water Co., Wissahickon formation	Sept. 25	40	7.3	.08	3.4	3.2	2.8	.7	8.5	3.4	3.2	15	22	54	F

CUMBERLAND COUNTY

32	Well ½-mile S. of Lees Cross roads, 120 feet, Tomstown limestone	Oct. 31	240	13	.78	67	9.1	1.6	1.2	204	7.7	4.9	29	205	50	F
35	Well 1½ miles N. of Newville, 76 feet, Martinsburg shale	Oct. 31	214	22	.57	39	14	9.8	1.8	135	55	3.2	.57	155	52	F
36	Spring at Mount Holly, Weverton sandstone	Oct. 31	19	9.1	.03	1.5	1.0	.6	.3	6.1	4.0	.5	.31	7.8	48	F
37	Spring at Big Spring, owned by Lindsay and Felin, Beekmantown limestone	Oct. 31	175	14	.12	50	8.3	.7	.7	168	7.5	1.4	11	159	50	F
38	Spring at Newville, owned by Newville Borough Stones River limestone	Oct. 31	258	17	.05	77	10	3.5	.9	254	11	1.8	15	234	52	F

DELAWARE COUNTY

51	Well at Village Green, 75 feet, Wissahickon formation	Sept. 26	126	20	4.0	14	6.7	6.4	2.2	30	40	9.6	.33	62	54	F
97	Well at Boothwyn, 49 feet, gabbro	Sept. 26	140	36	.21	14	7.4	8.6	1.5	56	4.6	12	26	65	54	F
110	Well at Brandywine Summit, 51 feet, Wissahickon formation	Sept. 26	85	28	4.1	11	4.2	5.8	1.4	43	4.3	5.2	11	45	54	F
118	Well at Elam, 106 feet, Wissahickon formation	Sept. 26	80	12	8.7	12	5.1	6.5	1.7	52	13	4.8	.45	51	-------	F
132	Well at Elam, 85 feet, serpentine	Sept. 26	111	23	5.4	4.2	18	2.6	.8	58	3.2	11	32	84	-------	F
138	Well at Booth Corner, 38 feet, gabbro	Sept. 26	69	12	.15	7.2	5.6	3.6	1.0	27	8.8	5.5	14	41	54	F
142	Well at Chadds Ford, 67 feet, Baltimore gneiss	Sept. 26	150	34	.08	16	6.9	6.8	1.9	23	14	6.2	57	68	55	F

Analyses of waters from southeastern Pennsylvania

(Parts per million. Numbers correspond to numbers in tables of well data for the counties)

FRANKLIN COUNTY

No.	Source, location, depth, formation	Date of collection, 1925	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
3	Well 3 miles NE. of Chambersburg, 40 feet, Beekmantown limestone	Oct. 31	424	28	.08	108	18	[b]6.1		362	27	18	8.2	344	50	H
9	Well 1⅓ miles W. of St. Thomas, 86 feet Beekmantown limestone	Oct. 29	270	11	.23	72	16	3.5	.8	248	27	2.0	18	246	52	H
11	Well 2⅔ miles E. of St. Thomas, 55 feet, Martinsburg shale	Oct. 29	174	18	.17	28	17	8.5	2.4	152	30	2.9	Trace	140	52	H
22	Well 3 miles SE. of Mercersburg, 18 feet Beekmantown limestone	Oct. 29	260	12	.06	66	14	[b]4.6		228	23	4.3	19	222	-------	H
26	Spring at Caledonia Park, owned by Pennsylvania Department of Forests and Water. Pre-Cambrian	Oct. 28	21	5.8	.03	2.2	1.7	.9	1.3	9.8	3.6	1.7	Trace	12	51	H
27	Pearl Spring, State Forest Reserve, Harpers schist	Oct. 29	22	5.2	.03	2.9	1.7	.6	1.1	9.8	7.4	.6	Trace	14	46	H
28	Spring at Mont Alto Park (Indian Spring), Antietam sandstone	Oct. 29	34	4.8	.03	1.6	1.6	2.2	1.8	12	5.1	.8	Trace	11	49	H
29	Spring 3½ miles W. of St. Thomas, owned by David Horn, Martinsburg shale	Oct. 29	45	12	.11	2.5	3.3	3.5	1.4	24	3.6	1.5	6.1	20	54	H
30	Spring 1 mile SE. of Aqua, Elbrook formation	Oct. 30	242	13	.12	61	18	[b]3.5		244	15	4.5	6.5	226	48	H
31	Spring at Cove Gap, owned by W. A. Reitzel, Juniata formation	Oct. 29	28	7.3	.07	3.3	1.4	1.5	.8	12	4.6	.50	1.5	14	50	H

LANCASTER COUNTY

No.	Source, location, depth, formation	Date of collection, 1925	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
4	Well 2½ miles WNW. of Honeybrook, 127 feet, Chickies quartzite	[d]Sept. 15	[e]27	4.1	.53	2.0	1.4	.6	.6	24	1.6	1.5	.0	[f]19	-------	F
7	Well at New Holland, 338 feet, Elbrook limestone	Oct. 1	483	12	.12	90	36	24	3.1	337	66	56	.80	373	54	H
10	Well at Blue Ball, 250 feet, Elbrook limestone	[d]Sept. 15	332	13	.15	66	32	2.0	3.2	259	31	12	47	296	-------	F

34	Springs at Christiana owned by Christiana Gravity Water Co., Baltimore gneiss	Sept. 24	34	7.4	.10	------	------	3.7	1.5	7.3	2.6	4.0	4.2	89	54	H
47	Springs at Strasburg, owned by Strasburg Borough, Baltimore gneiss	Sept. 23	19	5.0	.07	1.7	1.8	2.6	1.0	11	2.1	5.0	.27	12	51	H
48	Springs at Strasburg, owned by Strasburg Borough, Baltimore gneiss	Sept. 24	27	4.2	.07	2.6	2.5	3.0		8.5	4.7	6.0	3.9	17	51	H
55	Springs at Quarryville, owned by Quarryville Borough, Wissahickon formation	Sept. 23	100	11	.28	22	3.5	3.9		57	15	6.0	4.5	69	------	H
63	Springs at Ephrata, owned by Ephrata Borough, Triassic	Oct. 1	44	12	.15	6.9	2.6	1.3	.8	24	3.0	4.0	Trace	28	------	H
72	Well ½ mile S. of Ronks, 48 feet, Conestoga limestone	Sept. 24	311	10	.15	67	26	7.9		265	32	19	5.6	274	54	H
74	Well 1 mile E. of Lancaster, 152 feet, Conestoga limestone	Sept. 24	547	15	.09	107	39	27		388	72	58	1.7	427	54	H
76	Well 1 mile E. of Greenland, 105 feet, Conestoga limestone	Sept. 24	290	7.9	.10	72	9.4	11	7.1	217	30	22	1.0	219	------	H
78	Spring at Rocky Spring Park, owned by H. B. Griffith, Conestoga limestone	Sept. 23	264	10	.09	70	6.4	3.7	.8	187	37	8.0	.80	201	51	H
81	Spring 1 mile W. of Lampeter owned by Elizabeth A. Herr, Conestoga limestone	Sept. 23	230	10	.07	52	14	5.5		178	20	6.0	.75	187	52	H
91	Well at Truce, 72 feet, Wissahickon formation	Sept. 22	50	4.4	4.1	2.5	2.4	[b]13		30	4.0	7.0	7.7	16	------	H
99	Well at Oakryn, 63 feet, Peters Creek schist	Sept. 22	55	11	1.9	4.6	1.7	6.4		24	4.2	4.0	6.0	18	------	H
102	Well at Wakefield, 35 feet, Peters Creek schist	Sept. 22	406	14	.94	35	24	44		9.8	12	105	175	186	------	H
106	Well at Lyles, 40 feet, serpentine	Sept. 22	87	13	1.2	9.0	5.1	6.1		18	3.0	12	28	43	------	H
107	Well at Wrightsdale, 70 feet, serpentine	[d]Sept. 15	288	9.4	.60	30	15	24	2.1	15	6.4	72	89	136	------	F
114	Springs at Mountville, owned by Mountville Borough, Harpers schist	Sept. 23	80	6.5	5.1	5.5	4.8	8.9		7.3	5.2	13	21	33	54	H
115	Well at Mountville, (No. 1), 209 feet, Harpers schist	Sept. 23	83	18	1.5	10	8.1	5.3		56	11	7.0	Trace	58	53	H
126	Well at Rohrerstown, 126 feet, Conococheague limestone	Sept. 23	541	13	.19	96	40	24		357	81	40	22	404	53	H
132	Well at Salunga, 50 feet, Conococheague limestone	Sept. 21	889	14	.24	118	52	76		331	56	127	216	508	------	H
138	Well at Millersville, 64 feet, Conestoga limestone	Sept. 23	243	11	.07	63	6.9	7.2		[illegible]	18	12	1.7	186	------	H
149	Well at Rawlinsville, 55 feet, Wissahickon formation	Sept. 22	121	4.1	.38	6.9	7.9	21		17	5.4	30	33	50	------	H
151	Well ½ mile E. of McCalls Ferry, 63 feet, Wissahickon formation	Sept. 22	104	9.7	1.6	15	5.7	6.4		28	6.2	10	35	61	------	H

LEBANON COUNTY

6	Well at Myerstown, 27 feet, limestone	Oct. 1	242	12	.06	58	16	6.4		231	16	8.0	4.7	211	52	H
18	Well at Mt. Zion, 90 feet, Martinsburg shale	Oct. 2	91	13	.12	9.6	6.1	9.6		63	13	1.6	.60	49	54	H
20	Well at Lebanon, 402 feet, limestone	Oct. 2	485	32	.12	100	20	28		257	116	44	Trace	332	52	H
22	Well at Lebanon, 164 feet, limestone	Oct. 2	357	15	.06	76	18	22		251	49	22	26	264	52	H
27	Well at Iona, 185 feet, limestone	Oct. 2	218	9.7	.13	44	22	3.4		222	20	1.0	.40	200	54	H
31	Well at Lebanon, 150 feet, Martinsburg shale	[d]Sept. 15	197	17	.05	39	10	11	1.7	127	13	24	14	138	------	F

Analyses of waters from southeastern Pennsylvania

(Parts per million. Numbers correspond to numbers in tables of well data for the counties)

LEHIGH COUNTY

No.	Source, location, depth, formation	Date of collection, 1925	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
8	Well at Allentown, 324 feet, limestone	Oct. 4	356	13	.08	57	35	19	5.3	267	38	30	36	286	52	F
31	Spring at Mountainville, owned by Charles Erney, gneiss	Oct. 4	88	57	.16	2.0	1.4	2.7	1.4	13	5.8	1.3	.15	11	54	F
44	Spring ½ mile W. of Trexlertown, limestone	Oct. 4	150	12	.05	37	11	2.1	1.1	134	13	2.2	12	138	51	F
55	Well at Lanark. 262 feet, limestone	Oct. 4	184	22	.08	46	6.7	1.7	1.8	136	21	1.9	7.5	142	-------	F

MONTGOMERY COUNTY

No.	Source, location, depth, formation	Date of collection, 1925	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
11	Well at Limerick, 110 feet, Brunswick shale	Sept. 30	252	25	.15	48	24	12	1.2	234	6.4	19	14	218	52	F
30	Well at Eagleville, 490 feet, Lockatong formation	Sept. 30	283	13	17	47	23	22	1.9	283	3.8	7.0	.21	212	54	F
41	Well at Collegeville, 111 feet, Brunswick shale	Sept. 30	209	23	4.9	45	11	12	3.0	183	13	12	.88	158	-------	F
47	Well 1 mile SW. of Norristown, 186 feet, limestone	Sept. 30	75	33	.17	5.6	2.4	6.5	.6	41	3.4	2.0	.0	24	52	F
52	Well at Norristown, (No. 1), 410 feet, Stockton formation	Sept. 30	570	30	.06	72	49	20	3.5	[c]156	279	7.2	.69	381	55	F
59	Well at Norristown, (No. 8), 277 feet, Stockton formation	Sept. 30	234	41	.06	36	18	9.1	2.2	[c]143	44	5.5	8.0	164	54	F
95	Spring at Whitemarsh, owned by Ambler Spring Water Co., limestone	Sept. 28	248	14	.23	43	26	8.0	2.6	212	31	10	8.5	214	54	F
99	Well at Montgomery Square, 80 feet, Lockatong formation	Sept. 28	320	13	.27	66	23	15	2.7	254	37	22	16	259	54	F
104	Well at North Wales (No. 4), 157 feet, Lockatong formation	Sept. 28	199	25	.07	40	15	9.8	1.7	187	13	6.8	5.2	162	52	F
107	Well at North Wales (No. 7), 400 feet, Brunswick shale	Sept. 25	232	18	.06	47	17	9.4	2.1	[c]194	23	13	7.5	187	54	F
111	Wells at Lansdale, 325 to 1,100 feet, Brunswick shale	Sept. 28	201	32	.05	36	15	11	1.8	[c]173	15	8.0	2.5	152	-------	F
130	Well at Hatboro (No. 1), 300 feet, Stockton formation	Sept. 29	129	29	.07	16	4.6	10	1.4	41	12	11	21	59	-------	F

NORTHAMPTON COUNTY

4b	Well at Bangor, 500 feet, Martinsburg shale	Oct.	3	35	11	.03	5.7	2.2	1.3	.6	24	4.7	1.0	.27	23	50	F
10	Springs at Bangor, owned by Bangor Water Co., glacial drift	Oct.	3	70	3.8	.14	18	3.1	1.4	.7	60	7.7	1.5	1.5	58	52	F
20	Well at Wind Gap, 150 feet, glacial drift and talus	Oct.	3	26	4.5	.14	4.1	2.0	.8	.9	16	5.8	1.0	.10	18	50	F
22	Well at Nazareth, 400 feet, Martinsburg shale	Oct.	3	150	28	.23	27	7.9	3.6	1.8	[c]74	44	1.8	.10	100	52	F
23 and 24	Two wells at Nazareth, 130 and 325 feet, Martinsburg shale	Oct.	3	112	8.4	.06	18	6.0	4.9	2.4	61	30	2.2	.0	70	52	F
25	Well 2 miles NE. of Easton, 50 feet, Pre-Cambrian gneiss	Oct.	4	261	26	.74	56	8.4	9.0	2.7	105	70	24	.91	174	54	F
26	Spring at Easton, owned by C. K. Williams & Co., serpentine	Oct.	4	287	30	.19	62	17	4.2	2.1	194	50	11	12	225	-------	F
29	Spring 1 mile NW. of Easton, owned by Mrs. Leona Johnson, Beekmantown limestone	Oct.	4	300	11	.06	51	33	9.8	2.2	242	30	19	31	263	50	F
31	Well at Easton, 91 feet, limestone	Oct.	4	609	11	.19	93	52	38	7.7	359	95	58	73	446	52	F
36	Well at Green Pond, 125 feet, Conococheague limestone	Oct.	4	172	16	.08	30	18	4.7	4.0	[c]137	5.0	8.0	40	149	52	F
42a	Well 1 mile N. of Bethlehem, 1,012 feet Conococheague limestone	Oct.	4	278	17	.07	54	28	2.4	1.9	[c]194	71	8.5	3.6	250	52	F

PHILADELPHIA COUNTY

55	Well at Front St. and Snyder Ave.	7/24,	'29	692	16	.14	66	47	89	9.6	249	102	140	78	358	-------	F
57	Well at Swanson and Jackson Sts.	3/19,	'30	489	17	.06	52	35	55	4.5	187	78	83	53	274	-------	F

YORK COUNTY

1	Spring south of York, owned by York Water Co., Harpers schist	Nov.	1	49	2.7	.04	5.0	3.0	4.1	2.9	12	6.7	7.0	10	25	50	H
5	Well 1½ miles E. of Thomasville, 48 feet, limestone	Nov.	1	205	8.2	.19	54	13	4.4	2.1	183	14	3.5	20	188	52	H
6	Well 1½ miles NW. of Yocumtown, 56 feet, Triassic sandstone	Nov.	2	100	19	.46	19	3.2	3.9	.9	70	5.3	1.6	8.2	61	-------	H
8	Well 1¼ miles NW. of Yocumtown, 50 feet, diabase	Nov.	2	83	24	.20	5.5	4.3	6.8	1.3	49	4.6	5.0	1.5	31	52	H
9	Spring at York Haven, owned by Pythian Park, diabase	Nov.	2	222	25	.04	29	19	9.1	1.6	132	46	7.0	6.2	150	52	H
19	Well 3 miles NE. of Abbottstown, 22 feet, Triassic	Nov.	1	161	8.4	.17	27	14	9.4		90	54	8.0	7.1	125	52	H

[a] Margaret D. Foster (F), C. S. Howard (H).
[b] Calculated.
[c] Includes equivalent of small amount of carbonate.
[d] Collected in 1927.
[e] Includes Zn 5.7 parts per million.
[f] Includes hardness due to zinc.
[g] Determined.

INDEX

T

U

V

W

U. S. GEOLOGICAL SURVEY

DEPARTMENT OF INTERNAL AFFAIRS
TOPOGRAPHIC AND GEOLOGIC SURVEY

BULLETIN W-2, PLATE